



**Federal Aviation
Administration**

FY 2012 R&D Annual Review

September 2013

**Report of the Federal Aviation Administration to
the United States Congress pursuant to Section
44501(c) of Title 49 of the United States Code**

FY 2012 R&D Annual Review
September 2013

The *R&D Annual Review* is a companion document to the *National Aviation Research Plan* (NARP), a report of the Federal Aviation Administration to the United States Congress pursuant to Section 44501(c)(3) of Title 49 of the United States Code. The *R&D Annual Review* is available on the Internet at <http://www.faa.gov/go/narp>.

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Introduction

The Federal Aviation Administration (FAA) research and development (R&D) mission is to conduct, coordinate, and support domestic and international R&D of aviation-related products and services that will ensure a safe, efficient, and environmentally sound global air transportation system. It supports a range of research activities from materials and aeromedical research to the development of new products, services, and procedures.

The FAA R&D portfolio supports both the day-to-day operations of the National Airspace System (NAS) and the development of the Next Generation Air Transportation System (NextGen). To achieve balance between the near-, mid-, and far-term, the FAA has defined three R&D principles to focus and integrate its programs. The R&D principles help the FAA align, plan, and evaluate its R&D portfolio. The R&D principles are:

- **Improve Aviation Safety** - systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve aviation and space safety and achieve the lowest possible accident rate.
- **Improve Efficiency** - systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve access to and increase capacity and efficiency of the nation's aviation system.
- **Reduce Environmental Impacts** - systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will reduce aviation's environmental and energy impacts to a level that does not constrain growth.

The *R&D Annual Review* highlights the significant R&D accomplishments of the FAA and serves as a companion to the FAA *National Aviation Research Plan* (NARP). The significant accomplishments are organized by the three R&D principles described in Chapters 1 through 3 of the NARP.

R&D Principle 1 - Improve Aviation Safety

Systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve aviation and space safety and achieve the lowest possible accident rate.

Composite Structural Engineering Training (CSET) Requirements:

The Advanced Materials/Structural Safety Team completed the Composite Structural Engineering Training (CSET) requirements that assist FAA and industry personnel in attaining certification for developing composite aircraft. The FAA will use the CSET requirements in a training course that will address the current composite technologies seeking certification in aircraft product applications, including small airplane, rotorcraft, transport airplane, propeller, and engine components. The course will also cover current FAA safety and certification initiatives for composite technologies. This multi-year research effort covered a wide range of topics that included the following engineering aspects: materials and processes, manufacturing, structural design, proof of structures, and maintenance of composite structures. The research required developing detailed information in numerous technical areas, including: composite structural design, static-strength-proof of structure, damage resistance, durability, damage tolerance, and crashworthiness. The FAA developed the content for the requirements using information provided by academia, industry, and FAA research. The training requirements include instructional course material as well as a practical workshop. Furthermore, the FAA has conducted beta testing on the course with industry subject matter experts to align the material with accepted industry practices. The CSET will form the basis for an FAA Office of Certification training course required for FAA personnel dealing with composite structures engineering and will be available in 2013. (Advanced Materials/Structural Safety)



Typical Composite Aircraft

Impact Damage Formation on Composite Aircraft Structures:

The Advanced Materials/Structural Safety Team conducted research in the area of Wide Area High Energy Blunt Impact to better understand the effect of design philosophy for composite

aircraft structures under blunt impact. Researchers tested two full-scale, five-frame panels under impact loading, representing a collision of a typical ground service vehicle with an aircraft fuselage. The resulting damage in the first panel included widespread frame cracking with no externally visible signs of damage. Discussion with industry partners indicated this failure scenario was unexpected. An evaluation of the panel design showed that the shear ties were undersized for a typical transport aircraft. Due to the failure of the shear ties, the attached internal frames rotated and failed. The second test panel had stronger shear ties (7075 aluminum). The stronger shear ties in the second panel resulted in a higher load capacity (prior to damage initiation), that lead to localized failure near the site of loading in the frames where they joined to the shear ties. The exterior skin showed surface cracks (i.e., visible damage). Researchers are developing a modeling methodology to predict the onset, growth, and final extent of the damage (see Figure 1). This methodology will also identify criteria by which surface-visible damage develops because of soft contact impacts, such as from rubber bumper impact loading. Model inputs will be entirely based on measured data or best-matching properties, with no tuning of parameters relied upon to match test results. The FAA is designing supporting coupon and element level tests to support hierarchical methodology development.

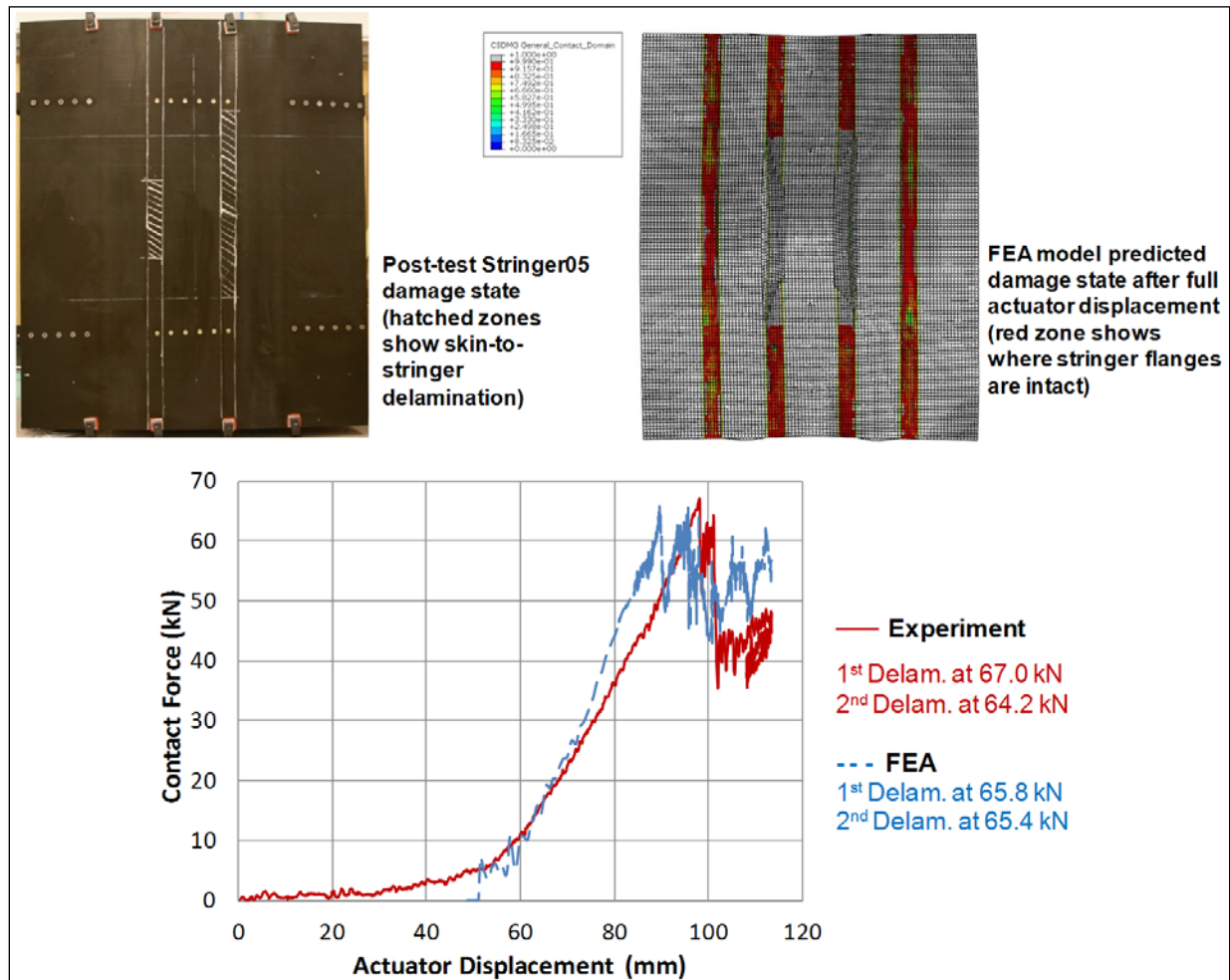


Figure 1: Analytically and Experimentally Determined Delamination Failure of Composite Panel

The industry partners provided key input that lead to the test panels more accurately reflecting real aircraft and, thus, provided maximum benefit for the research program. Researchers will summarize key findings to allow analysts to predict blunt impact damage onset and damage extent and to assess whether the event will be visibly detectable. These findings will support the FAA Transport Aircraft Directorate policy for guidance in certification requirements of full-scale, wide-area, high-energy blunt impact structural impact testing expected in the next two years. (Advanced Materials/Structural Safety)

Drugs and Alcohol Found in Civil Aviation Accident Pilot Fatalities:

The FAA's Office of Aerospace Medicine sets medical standards needed to protect the public and pilots from death or injury due to incapacitation of the pilot. The Bioaeronautical Sciences Laboratory conducted a study to determine the extent of drug use in pilots who have died in aviation accidents from 2004 to 2008 and to determine the types of drugs most commonly found by extracting research data from the FAA toxicology database for all pilots who died in aviation accidents between 2004 and 2008. The laboratory received and tested specimens from 1,353 pilots; 507 of which were found to be taking drugs with 92 having ethanol in excess of 0.04 g x dl(-1). Researchers also compared this report with previously published reports to determine trends in drug use by pilots who have died in aviation accidents over the past 20 years. Researchers discussed the factors that could influence drug trends. Diphenhydramine, an H1 antihistamine with impairing properties, is the most commonly found drug in pilots who died in aviation accidents. Results of this study are published in *Drugs and Alcohol Found in Civil Aviation Pilot Fatalities from 2004 to 2008*. *Aviation, Space, and Environmental Medicine*. Canfield, D.V., Dubowski, K.M., Chaturvedi, A.K., and Whinnery, J.E. 2012;83(9):764–770. (Aeromedical Research)



FAA Toxicology Testing on Pilots Who Die in Aviation Accidents

Trends of Amateur-built Aircraft Accidents:

The FAA Civil Aerospace Medical Institute (CAMI) collects biological samples from fatally injured pilots in aviation accidents involving all types of aircraft, including amateur-built aircraft. During their investigation, CAMI researchers analyze these samples for fire gases, ethanol, and drugs. CAMI's Biochemistry Research Team evaluated amateur-built aircraft accidents that occurred between 1990 and 2009. In addition, CAMI obtained from the National Transportation Safety Board's (NTSB) aviation accident database the probable cause and factor in amateur-built aircraft mishaps. Of 6,309 aviation accidents from which CAMI received postmortem samples, 979 (16%) involved amateur-built aircraft. The highest number of aviation mishaps occurred during summer, which was true with amateur-built as well as with all other aircraft. There was a decreasing trend in accidents of non-amateur-built aircraft, whereas there was an increasing trend in accidents of amateur-built aircraft. Of the 979 accidents CAMI studied, 392 pilots tested positive for ethanol and/or drugs. CAMI found ethanol in 29 pilots, drugs in 345, and ethanol plus drugs in 18. Additionally, for ethanol/drug-related accidents, CAMI observed a decreasing trend with non-amateur-built aircraft and an increasing trend with amateur-built aircraft. Of the 392 amateur-built aircraft, 388 (99%) were flying under the general aviation (GA) category. In the 392 pilots, 238 (61%) held private pilot flying certificates and 260 (66%) held third-class airman medical certificates. The spectrum of drugs found in the amateur-built aircraft-accident pilot fatalities was consistent with commonly used drugs in the general population. The percentage of pilots wherein CAMI detected prescription drugs was 26 percent for amateur-built aircraft, whereas it was 16 percent for non-amateur built aircraft, and 18 percent for all aircraft. CAMI determined ethanol/drug use and medical condition to be a cause or factor in 42 (11%) of the 385 ethanol/drug-positive amateur-built aircraft accidents investigated by the NTSB. However, CAMI cannot rule out the contributory role of the mechanical malfunction of home-built aircraft in the observed increasing trends in their accidents, with or without ethanol and/or drugs. The increasing trend of such accidents is of significant concern. *Toxicological Findings in Fatally Injured Pilots of 979 Amateur-Built Aircraft Accidents*. Office of Aerospace Medicine Technical Report DOT/FAA/AM-11/21. Chaturvedi, A.K., Craft, K.J., Hickerson, J.S., Rogers, P.B., and Soper, J.W. (Aeromedical Research)



Laser Illumination of Flight Crewmembers by Altitude and Chronology of Occurrence:

The illumination of flight crew personnel by lasers while they perform landing and departure maneuvers has concerned the aviation community for the past two decades. The FAA's CAMI Vision Research Team examined the frequency of illumination events in the United States (U.S.) by altitude and chronology of occurrence to determine where and when aviators and the flying public may be at greatest risk. CAMI maintains a database of reports of aircraft illuminated by high-intensity light sources. In this study, CAMI researchers collected and analyzed reports of flight crewmembers exposed to lasers between January 1, 2004 and December 31, 2008.

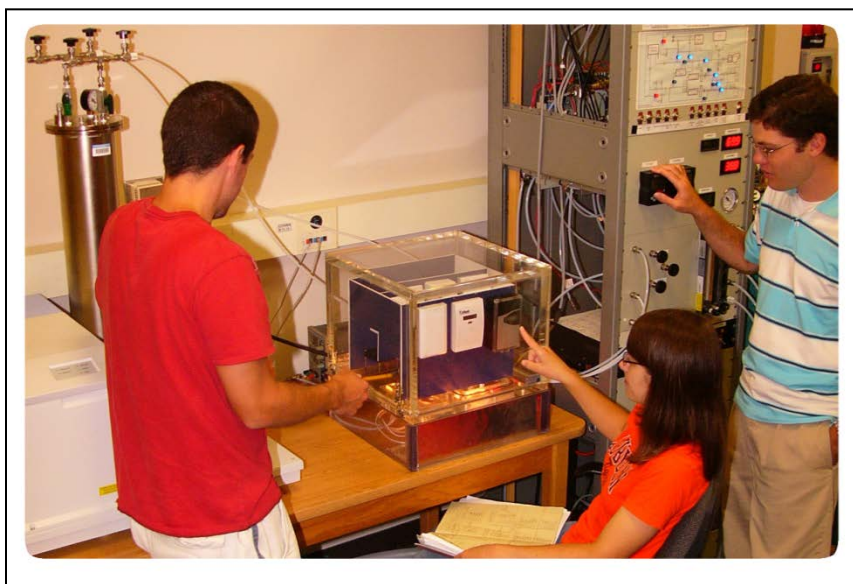
Cockpit illuminations at or below 2,000 feet increased from 12.5 to 26.7 percent over the five-year study period, while the percentage of illuminations between 2,000 and 10,000 feet decreased from 87.5 to 58.4 percent. The months of November and December had the highest frequency of laser events (23%), while May and June had the least (12%). Sunday was the most likely day for an aircraft to be illuminated (18.3%), while Wednesday was the day least likely for such an incident (15.4%). More than 91 percent of all aircraft illumination events occurred between 6 p.m. and midnight. The continuing increase in the number of laser illuminations reported at or below 2,000 feet represents an escalating threat to aviation safety. Information provided in this study may allow law enforcement to deploy their resources more efficiently to apprehend those responsible for these crimes. Details of the research findings are available in *Laser Illumination of Flight Crewmembers by Altitude and Chronology of Occurrence*. Aviation, Space, and Environmental Medicine. Nakagawara, V.B., Montgomery, R.W., and Wood, K.J. 2011;82(11):1055–60. (Aeromedical Research)



Engine Oil Decomposition Behavior during Simulated Bleed Air Contamination Events:

The potential for contamination of the bleed air supplies of commercial aircraft due to chronic or acute engine oil leaks has worried commercial aviation for years. Researchers from the Airliner Cabin Environment Research (ACER) team of the National Air Transportation Center of Excellence for Research in the Intermodal Transport Environment (RITE) have analyzed the decomposition products of typical jet engine oils using thermogravimetric analysis, Fourier transform infrared spectroscopy (FTIR), and mass spectrometry. Many jet engine oils contain tricresyl phosphate (TCP) as an additive due to its excellent anti-wear properties. However, the

additive also raises concerns for human safety and health due to potential exposure to TCP and its isomers as a result of engine oil leaks contaminating the bleed air supply. The oil samples investigated included: BP Turbo Oil 274, BP Turbo Oil 2380, Aeroshell Turbine Oil 560, and Mobil Jet Oil II. Researchers heated the samples in air from room temperature to 650° C at 10°C/min. Experimental data indicate that all four oils exhibit maximum decomposition rates at temperatures of 301 - 326° C. Bleed air supply can be exposed to these temperatures during high power engine operations, from take-off to the top of climb. Mass spectrometry analyses indicated the presence of various hydrocarbons during the oil decomposition experiments (e.g., C_2H_5 , C_2H_6 , CH_2OH , CH_3OH , C_3H_3 , and C_3H_7) and FTIR indicated the presence of carbon dioxide (CO_2), carbon monoxide (CO), and water vapor (H_2O) as well as perhaps methanol (CH_4O) and formaldehyde (CH_2O). The FAA is conducting additional research using gas chromatography/mass spectroscopy to understand the complex mixture of reaction products better. Additional details of the research appear in *Principal Component Analysis (PCA) Application to FTIR Spectroscopy Data of CO/CO₂ Contaminants of Air*. [AIAA-2011-5091](#). Haney, R.L., Siddiqui, N., Andress, J.R., Fergus, J.W., Overfelt, R.A., and Prorok, B.C. AIAA 41st International Conference on Environmental Systems, Portland, Oregon, July 17–21, 2011. (Aeromedical Research)



Analyzing the Decomposition Products of Typical Jet Engine Oils

Commercial Sensor Performance for Detection of Simulated Bleed-Air Contamination Events:

Detection of bleed-air contamination events using reliable air quality sensors is a goal of many within the aviation community. Researchers from the ACER team of RITE are investigating commercially available, non-dispersive infrared (NDIR) sensors for CO_2 and electrochemical sensors for CO due to their considerable promise for aircraft measurements of these gaseous contaminants. Most of the commercial NDIR-based CO_2 sensors have shown repeatable performance for a variety of CO_2 levels, but they would require specialized calibration procedures for operation in aircraft. Many of the commercial CO sensors also demonstrated good performance for multiple CO concentration levels. The FAA has evaluated a custom

wireless sensor network in a Boeing 767 mock-up cabin section to verify the feasibility of its use in airliner cabins. The sensor network consisted of 12 wireless sensor units and a base station. The research indicates that NDIR and electrochemical sensor technologies are reliable methods to measure CO₂ and CO, respectively, and commercial units are available with potential for aircraft applications. However, existing sensor packaging as well as sensor maintenance and calibration methods will have to be adapted to the unique environment, and more stringent performance requirements will have to be anticipated for aircraft. Additional details of this research appear in *Sensors and Prognostics to Mitigate Bleed Air Contamination Events*, RITE-ACER-CoE-2012-05. Overfelt, R.A., Jones, B.W., Loo, S.M., Haney, R.L., Neer, A.J., Address, J.R., Yang, X., Zitova, A., Prorok, B.C., Fergus, J.W., Simonian, A.L., Kiepert, J., Pook, M. and Anderson, M. April 2012. (Aeromedical Research)



Boeing 767 Mock-up Cabin Used to Evaluate a Custom Wireless Sensor Network

FAA/NASA Sponsored LS-DYNA Aerospace Users Group:

The FAA and National Aeronautics and Space Administration (NASA) helped establish the LS-DYNA finite element code Aerospace Quality Control Users Group in 2003. The FAA and NASA established this group after FAA research programs identified significant differences in results from different computer platforms and versions of LS-DYNA. Moreover, they established this group to assure that aerospace industry users of LS-DYNA would have their modeling problems continually run through several computer platforms and versions of LS-DYNA to maintain accuracy and performance. Participants in this group consist of several major engine manufacturers, including Boeing, Pratt & Whitney, General Electric (GE), Honeywell, Williams, Rolls Royce, HondaJet, and FTT. This quality control system is modeled after an established system by the Livermore Software Technology Corporation (LSTC), developer of LS-DYNA for the automotive industry.

On June 6, 2012, an annual review meeting took place at LSTC. During this meeting, the FAA William J. Hughes Technical Center (WJHTC), George Washington University (GWU), Ohio State University (OSU), and Central Connecticut State University presented on the FAA-sponsored research in material model development. The users group incorporated six aerospace models into the aerospace group generic aerospace problem set: four models on engine-fan rig blade out and two on engine-fan fabric model for Kevlar. The users group also released a draft of the aerospace guidelines that the group is currently reviewing and editing. The users group anticipates releasing a completed version of the Aerospace Users Guide in FY 2013. In addition, the users group Website has been completely overhauled and contains several generic models as well as suggestions for using LS-DYNA for aerospace impact applications. (Aircraft Catastrophic Failure Prevention Research)

Turbine Engine Containment Titanium Material Testing and Analysis:

An increasing number of engine and aircraft applications are relying on proprietary analysis tools to show compliance with FAA regulations, complicating the FAA's task of making compliance findings. One critical aspect that varies among the proprietary tools is the material models used for the analysis. The goal of this FAA research is to have a publically available tool with validated material models for aircraft materials. This will allow FAA engineers to validate the proprietary tools and streamline the certification process.

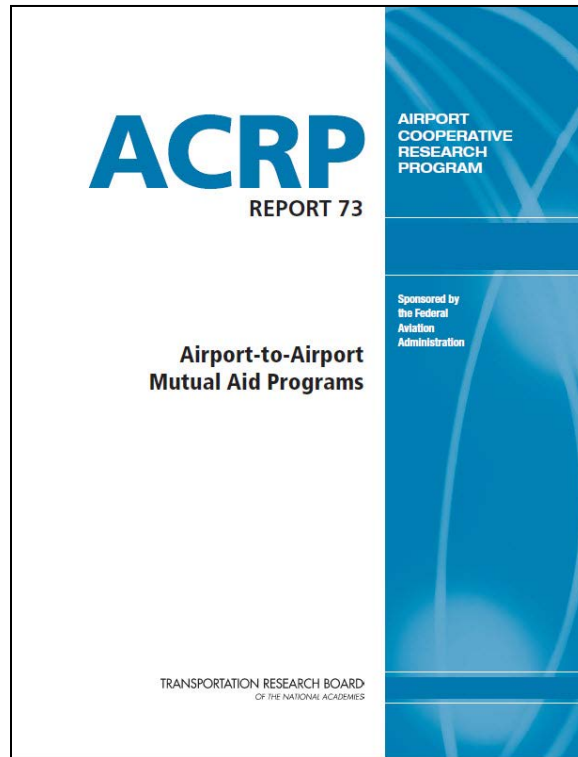
In 2012, FAA research concentrated on developing a titanium material model for the LS-DYNA code. Under an FAA grant, OSU completed a series of material characterization tests on 0.5" titanium 6Al-4V material. In FY 2012, OSU planned and completed over 200 plasticity and failure strain tests. OSU sent the test data to GWU for incorporation into the LS-DYNA material model that is under development. GWU analyzed and incorporated the tension and compression tests into the MAT224 material model. In FY 2013, researchers will analyze and incorporate the remaining tests into the titanium material model. (Aircraft Catastrophic Failure Prevention Research)

Airport-to-Airport Mutual Aid Programs:

Airports practice and understand working with their local community mutual aid organizations in responding to airport emergencies. However, when it comes to community-wide disasters (e.g., hurricanes, earthquakes) adversely affecting airport operations, airports may not be the first priority in the deployment of mutual aid assets. Airports are excellent resources for other airports during these disasters in that they have the exact type of asset and human resources with the knowledge to assist in the unique operating requirements of airport systems. Two grassroots organizations have been created to provide these resources: the Southeastern Airports Disaster Operations Group (SEADOG) and the Western Airports Disaster Operations Group (WestDOG), known collectively as the DOGs. The DOGs serve as a mechanism to assist afflicted airports and to coordinate with airports seeking to provide assistance, much in the same way as utility companies provide support for one another. Airports are interested in participating in such groups, but with known financial, legal, and logistical hurdles, they have been hesitant to commit

formally. With other industries having resolved or worked within these constraints, further research is necessary to help airports develop and implement airport-to-airport mutual aid programs (MAPs).

Through this research, the Airport Cooperative Research Program (ACRP) prepared a guidebook titled *Airport-to-Airport Mutual Aid Programs* to help public airport operators of all sizes and types to develop and implement national or regional airport-to-airport MAPs to plan, assess, respond, and recover from an event that adversely affects operations of the airport. (Airport Cooperative Research Program – Safety)



Guidelines for Utilizing Acoustic Energy to Deter Birds on Airports:

Increases in reported strikes between aircraft and wildlife, in particular birds, continue to drive the pursuit of solutions to the bird strike problem. Most bird strikes with aircraft occur in the vicinity of airport property; i.e., below 3,000 feet above ground level and during the take-off and landing phases of flight. The use of directed energy (e.g., microwaves, lasers and sound) has recently been proposed as a potential method for deterring birds from being present in the key operational areas of the airport. In FY 2012, the FAA completed a study to determine if acoustic hailing devices (AHDs) of the type used by military and police organizations for crowd control could be applied effectively and safely to wildlife management on airports. AHDs are similar to a loud speaker, yet produce a much stronger acoustic output in the form of a focused beam and can be heard with clarity at ranges of up to five miles or more. Modes of operation include: manual direct control of mobile units mounted on vehicles; manual-remote controlled fixed units deployed to select locations on tripods; and automated systems controlled by sensors, such as

radars that are capable of detecting and locating bird targets. The focus of the study was determining whether AHDs can be used safely in the complex operational environment of the airport where airport personnel, passengers, and sensitive navigational equipment could potentially be subjected to exposure of high levels of acoustic energy if even for short periods of time. After collaborating with AHD users at Offutt Air Force Base, Nebraska conducting independent field demonstrations and field measurements at the FAA's WJHTC, New Jersey and Philadelphia International Airport, Pennsylvania (see image below), and working closely with AHD manufacturers, the Airport Technology R&D Branch was able to determine that AHDs can be used safely in the airport environment. The result was the development of a preliminary concept of operations document describing methods and safety guidelines for using AHDs on airports as wildlife deterrents. A second related study focusing on the effectiveness of the AHDs to reliably manipulate the behavior of hazardous bird species (i.e., those that cause significant damage when struck by aircraft), will commence in FY 2013 and be conducted in collaboration with the U.S. Department of Agriculture APHIS Wildlife Services National Wildlife Research Center in Sandusky, Ohio. (Airport Technology Research Program – Safety)



Field Testing Acoustic Energy Technology

Full-Scale Evaluation of Methods for Fighting Cargo Container Fires on Freighter Aircraft:

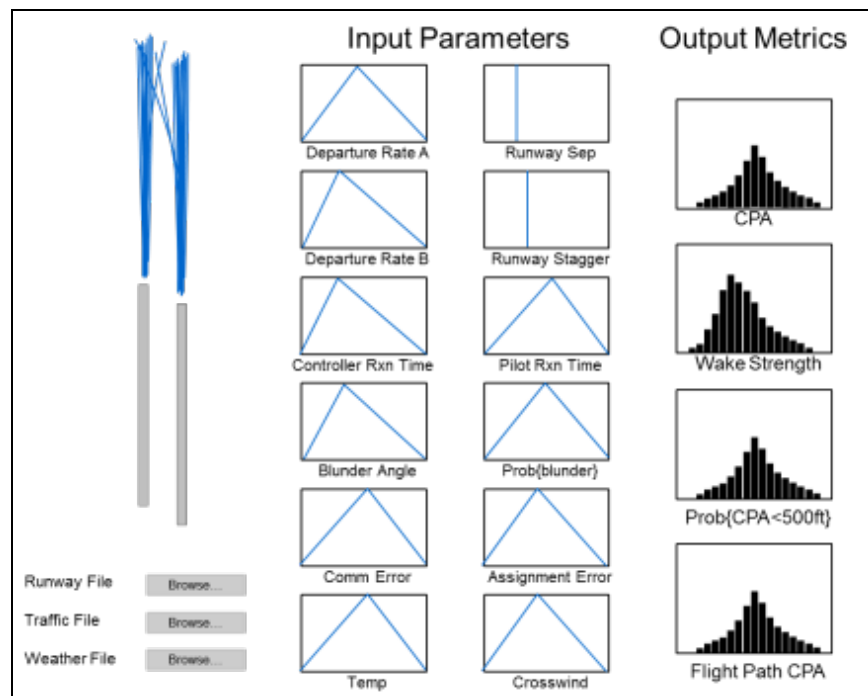
In 2009, in FAA Advisory Circular (AC) 150/5210-17B, *Program for Training of Aircraft Rescue and Firefighting Personnel*, the FAA added freighter aircraft familiarization as a requirement for Aircraft Rescue and Fire Fighting (ARFF) training. The ARFF research program initiated a project on freighter aircraft firefighting to develop tactics and strategies for handling these emergencies on airports. For FY 2012, part of the research effort entailed conducting full scale interior fire tests inside a freighter aircraft. FedEx donated an Airbus A310 freighter aircraft (N407FE) to aid the FAA in this research effort. It was decommissioned in Victorville, California at the Southern California Logistics Airport (SCLA) and salvaged for parts before being donated to the FAA. SCLA was the location where the fire testing was conducted. This series of tests demonstrated the effectiveness of certain firefighting tactics and strategies on specific cargo scenarios with various types of unit load devices or cargo containers. Twelve test scenarios totaling over 40 full scale fire tests were performed. These tests of firefighting tactics helped to develop scientifically based recommendations on how to mitigate cargo fires in freighter aircraft. These recommendations will enhance airport fire fighter's preparedness. (Airport Technology Research Program – Safety)



Testing of Cargo Aircraft at the Southern California Logistics Airport

Measuring the Safety of NextGen Runway Operations:

In FY 2012, the Center for Advanced Aviation System Development (CAASD) completed research to develop a simulation tool that provides a quantitative assessment of the safety of proposed NextGen concepts. The use of this type of quantitative assessment tool is in keeping with guidance and best practices of a Safety Management System (SMS) approach to assessing operational changes. The simulation capability is data-driven, modular, and designed to yield analytic results compatible with an SMS approach. The initial application of this approach was the development of a fast-time simulation to determine levels of safety associated with NextGen runway operational concepts for parallel as well as non-parallel runway geometries. The simulation supports decisions by facilitating “what-if” scenarios, the treatment of controller mitigations, and sensitivity analysis. The simulation also incorporates these capabilities in a graphical user interface that facilitates an end-to-end analytic process without the need to resort to an external data analysis tool. Simulation input parameters and output metrics appear below.



Simulation Input/Output Parameters

A significant enabling activity was the development of trajectory models that are useful in a Monte Carlo simulation for the purposes of risk analysis. Rather than using static aircraft performance specifications, the trajectory models are driven by empirical data. A hybrid of statistical modeling methods was used to create realistic synthetic position models from the original source data, which in turn are used by the simulation to introduce departure and arrival trajectories. Aircraft separations are recorded for further analysis, as are wake vortex encounters and their corresponding strengths.

FY 2012 research focused on application of the model to measure the effects of various timing and separation strategies for mitigating the risk of wake vortex encounters during parallel runway operations. The model facilitated the handling of relevant parameters and their random distribution: departure release timing, crosswind and headwind components, and aircraft velocity profiles. By iterating through a range of departure timing options and a range of environmental conditions prevalent at a particular airport, analysts were able to converge on a range of timing options that would limit the likelihood of wake vortex encounters to within prescribed target levels of safety. Simulation output of wake vortex encounter probability appears in Figure 2. (Center for Advanced Aviation System Development)

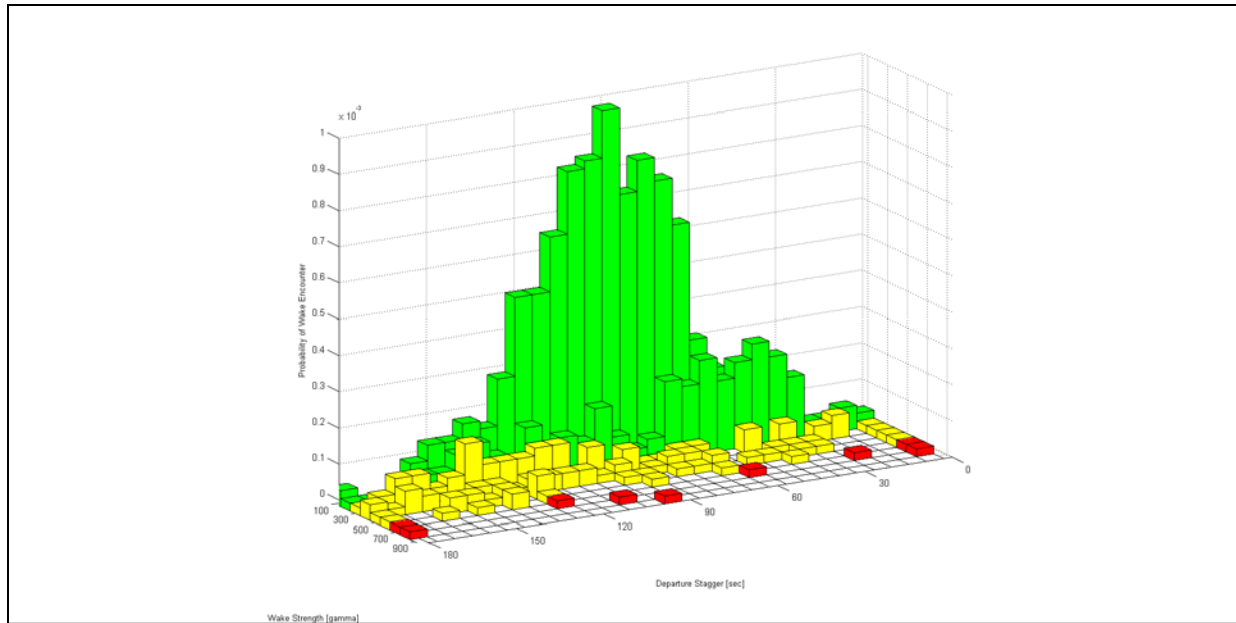
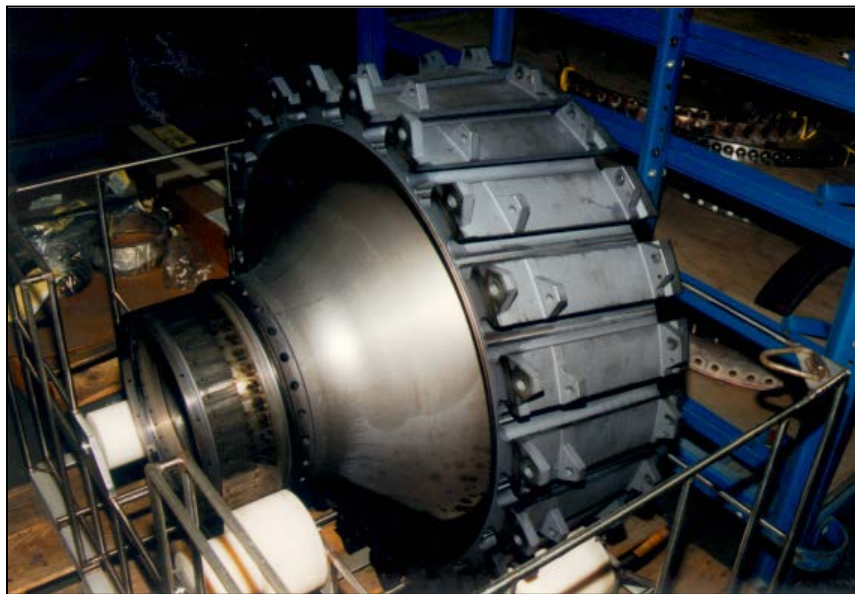


Figure 2: Simulation Output: Probability of Wake Vortex Encounters

Industrial Specification for Ultrasonic Inspection of Critical Rotating Titanium Jet Engine Parts:

The most important parts in modern jet engines from a safety aspect are the rotating disk components. A typical disk, shown below, can weigh over 100 pounds and reach rotational speeds of over 10,000 rotations per minute during flight. Failure of one of these parts can result in a catastrophic incident, sometimes so severe that it damages the aircraft structure with fragments of the shattered disk.



Typical Jet Engine Rotating Disk

To prevent such failures, inspection plays a critical role in management philosophy for commercial engine life, as described in AC 33.14-1 Damage Tolerance for High Energy Turbine Engine Rotors. Inspection is used for each component to assure that disks containing defects that could result in catastrophic failure of the engine do not enter service.

Researchers measure inspection effectiveness using a statistical assessment known as probability of detection (POD), with values measured during the POD process serving as inputs to the life management calculations. Researchers at the FAA WJHTC worked with the FAA Engine and Propeller Directorate staff to define research efforts of Iowa State University and major engine manufacturers to generate representative POD curves for billet and forging inspection. These curves are crucial in the calculation of reliable residual life predictions for engine disks. It is critical that the inspection procedures used to obtain the data for the POD curves are carefully documented. Deviation from the procedures used in the FAA program could result in significant changes in the resultant ultrasonic detection capability, causing large changes in the predicted life of the rotor parts.

In addition to the development of POD curves, the FAA worked with the industry partners to publish a new SAE (Society of Automotive Engineers, now commonly known as SAE International) industry specification now available to the aviation industry. The specification provides details to guide inspection using either amplitude only or amplitude and signal-to-noise rejection criteria. SAE International published the new standard *Ultrasonic Immersion Inspection Titanium and Titanium Alloy Forgings Premium Grade (AMS2636)* in 2012. Some of the most important benefits derived from the creation of this important specification include the following:

- It is the only public document defining important titanium forging ultrasonic testing (UT) parameters such as instrumentation, calibration, and accept/reject criteria.
- It is a reference specification for companies and institutions outside the jet engine manufacturing industry that are not familiar with the requirements for UT inspection of titanium forgings.
- It provides a standard for the generation of consistent, reliable capability (POD) data for future UT inspections of titanium forgings.
- It enables the FAA to reference a publicly available standard procedure for UT inspection of titanium forgings in future Policies and Directives.

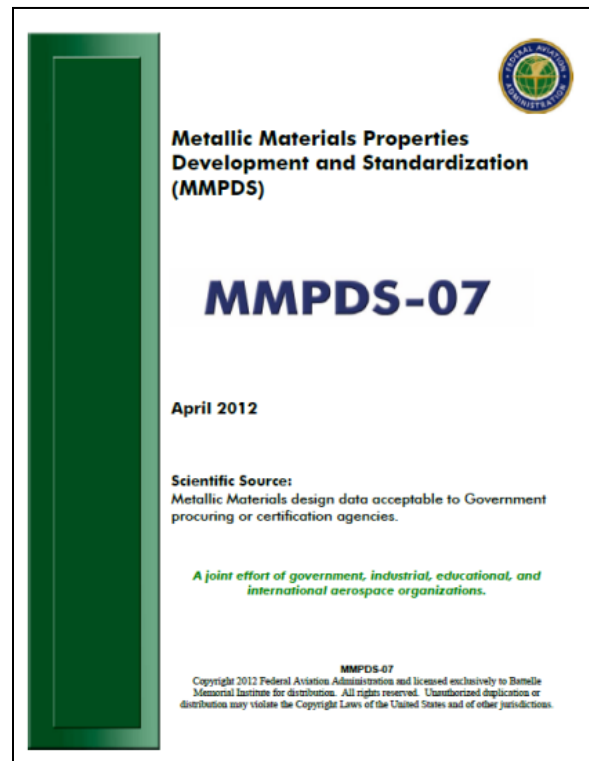
AMS2636 represents the combined efforts of the FAA, Iowa State University, and the major original equipment manufacturers in the engine manufacturing industry. As such, it is a significant benchmark in the FAA's effort to reduce the risk of disk rotor failures in future jet engines. (Continued Airworthiness)

Metallic Materials Properties Development and Standardization (MMPDS):

The Metallic Materials Properties Development and Standardization (MMPDS) is an effort led by the FAA to continue the handbook process entitled *Metallic Materials and Elements for*

Aerospace Vehicle Structures (MIL-HDBK-5). The handbook is recognized worldwide as the most reliable source for verified design allowables needed for metallic materials, fasteners, and joints used in the design and maintenance of aircraft and space vehicles. Consistent and reliable methods are used to collect, analyze, and present statistically based aircraft and aerospace material and fastener properties.

The objective of the MMPDS is to maintain and improve the standardized process for establishing statistically based allowables that comply with the regulations, which is consistent with the MIL-HDBK-5 heritage, by obtaining more equitable and sustainable funding sources. This includes support from government agencies in the Government Steering Group, industry stakeholders in the Industry Steering Group, and from profits selling the handbook and derivative products. Toward this goal, the commercial version of the MMPDS-07 was released April 2012. This release contained a substantial upgrade to the handbook with the addition of eight new metallic materials, including three aluminum-lithium alloys. (Continued Airworthiness)

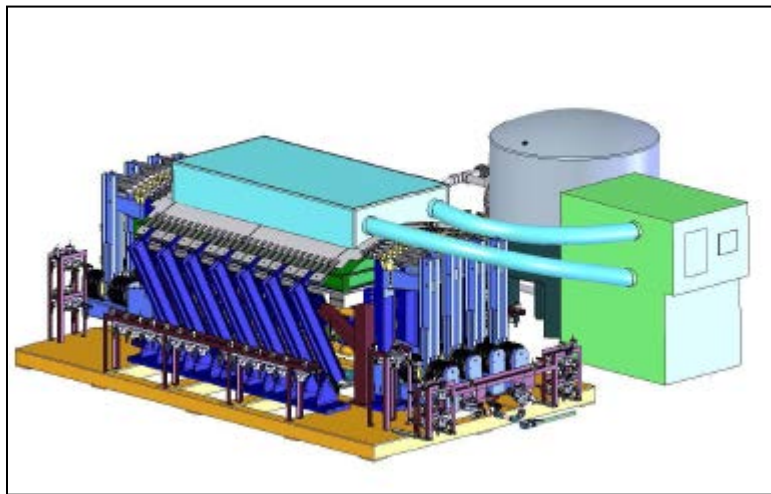


Modifications to the FAA's Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) Facility for Mechanical and Environmental Loading of Fuselage Structure:

On September 18, 2012, researchers verified enhancements to the FAA's Full-Scale Aircraft Structural Test Evaluation and Research (FASTER) fixture for mechanical and environmental loading capabilities. The FAA added this unique feature to the fixture as part of the Cooperative Research and Development Agreement (07-CRDA-0236) between the FAA Airport and Aircraft Safety R&D Group (now known as the Aviation Research Division) and The Boeing Company, a cost-share arrangement leveraging resources to conduct research into areas of safety and

structural integrity of bonded repairs. The FAA is using the new capability to gain a better understanding of the environmental durability and damage tolerance aspects of bonded repair technology to fuselage structure.

This environmental system consists of a remote conditioner to control temperature and humidity as well as a chamber on the test panel to contain the environment. The FAA fully integrated the environmental system with the fixture's mechanical loading system for synchronous mechanical-temperature-humidity loading profiles. With this new enhancement, the FAA can now test fuselage panels under a variety of operating environments ranging from hot-wet (165° F and 85–95% humidity) to cold-dry (-25° F and tending toward saturation) conditions. (Continued Airworthiness)



Modifications to FAA's FASTER Fixture for Mechanical and Environmental Loading Capabilities

Bonded Repair Technology:

Under a CRDA, the FAA and The Boeing Company are investigating the safety and structural integrity of bonded repair technology through testing and analysis of metallic fuselage panels using the FAA FASTER facility. The program objectives are to characterize the fatigue performance of bonded repairs under simulated service load (SL) conditions and to investigate tools for evaluating and monitoring the repair integrity over the life of the part.

The FAA is undertaking a phased approach in this research. Researchers completed the initial phase, in FY 2010, by demonstrating that properly designed and installed bonded repairs are durable under fatigue and can effectively contain large damage under severe static loads in excess of ultimate load requirements. The second phase, concluded in FY 2012, was characterized by the fatigue behavior of under-designed, partially disbanded, compliant and damaged repairs to mid-bay cracks in metallic fuselage structure to evaluate repair integrity. To assess the abilities of analytical methods and monitoring systems, researchers intentionally made repair patches deficient to allow damage growth in the form of crack propagation and disbonding during fatigue cycling. The FAA performed full-scale fatigue tests using a Boeing 727 fuselage

panel. Researchers tested both boron/epoxy (B/Ep) and aluminum repair patches with various anomalies under SL conditions. Additionally, researchers impacted several patches to simulate hail and tool drop events.

The FAA monitored the damage formation and growth of cracks and disbonding throughout the Phase 2 test using a variety of nondestructive inspection (NDI) methods, including visual inspections, eddy current, flash thermography, resonance ultrasonics, and computer-aided tap tester. In addition, they used a prototype piezoelectric-based structural health monitoring (SHM) system to assess and demonstrate its abilities to determine the condition of damage in the repair patches. Researchers obtained full-field strain and displacement of the patch and the surrounding regions using the digital image correlation (DIC) method.

In general, the ability to detect growing flaws under bonded patches and monitor effectiveness of repair using NDI and SHM was demonstrated, as shown in Figure 3a. Researchers assessed several parameters that affect repair performance, including under-designed, partially disbonded, and impacted repairs. Results showed that fatigue performance of a repair in effectively containing damage reduces as the repair quality degrades, as shown in Figure 3b. Impact damage caused both crack extension and disbonding in the repairs; however, there was no subsequent damage growth during fatigue cycling as indicated by NDI and DIC, as shown in Figure 3c. The third and final phase of this program will focus on the effects of environment on the durability and fatigue performance of bonded repairs. (Continued Airworthiness)

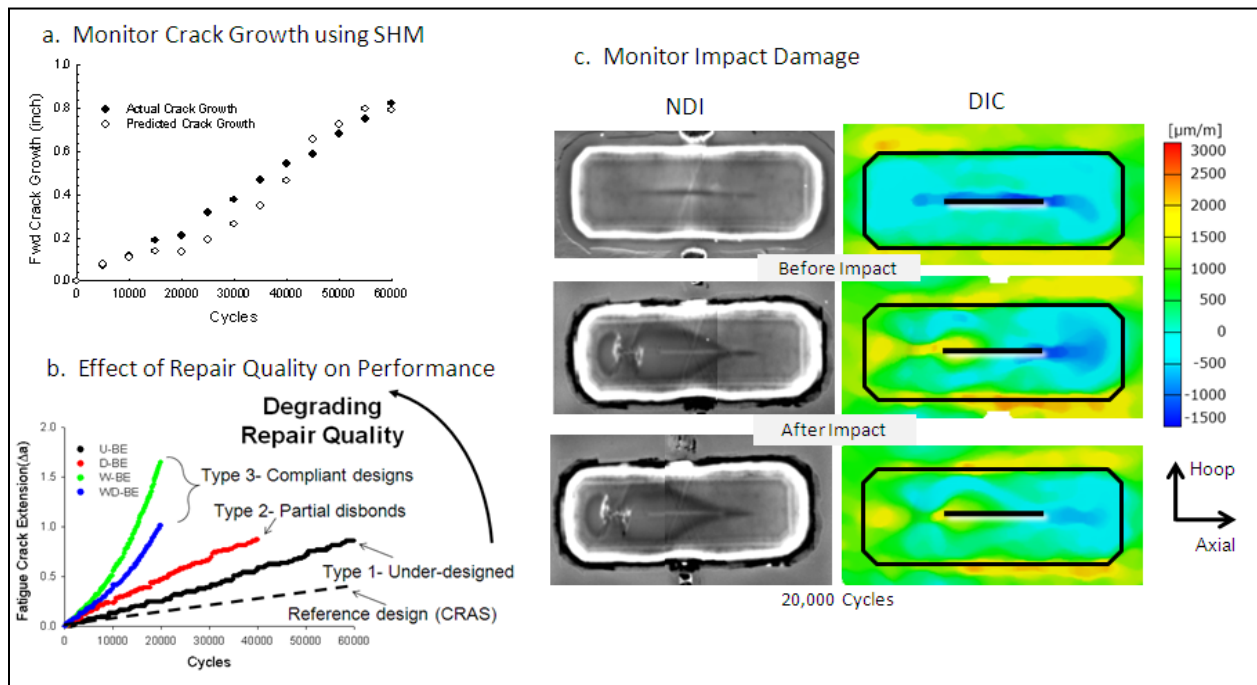


Figure 3: Representative Results from Bonded Repair Technology (Phase 2) Testing

Assessment of Advanced Aluminum-Lithium (Al-Li) for Primary Structure:

The latest generation of advanced aluminum-lithium alloys (Al-Li) purports to offer weight savings, compared to conventional aluminum alloys, while maintaining mechanical performance. Al-Li alloys, such as 2196 and 2198, have a lower density, higher modulus, and improved resistance against corrosion over the widely used 7xxx and 2xxx series alloys. Bombardier plans to use these Al-Li alloys for the fuselage skins, stringers, stiffeners, frames, floor beams, and seat tracks of their new C-Series aircraft, as shown in Figure 4a. Previous generations of Al-Li were plagued with issues that precluded them from use in aerospace applications, such as highly anisotropic behavior, low elongation and ductility, low transverse toughness, and inadequate fatigue properties.

While the latest Al-Li alloys are reported to have minimized these effects, there is a lack of publically available material properties to substantiate thoroughly the performance of these latest generation Al-Li alloys. This program provides an independent assessment of durability and damage tolerance capabilities of 2196 and 2198 Al-Li alloys. The purpose is to assess the unique mechanical properties of these Al-Li alloys when used for airplane primary structure. This program is leveraging resources and using the expertise of several organizations, including Constellium, Bombardier, NASA, Naval Air Systems Command, the University of Dayton Research Institute, and the FAA. The FAA is assessing and comparing several properties with baseline 2024-T3 and 7075-T6 alloys, including static properties, fatigue life and fatigue crack growth performance, corrosion resistance as well as the damage and durability aspects. The intent of this program is to develop the knowledge base to ensure the safe implementation and application of Al-Li material for airplane primary structure.

The initial phase of testing reveals that the static properties of 2198, namely tensile yield and ultimate strengths, are higher than MMPDS-published A and B values. In addition, anisotropic behavior is more evident in thicker gage material, particularly in the 45° direction, as shown in Figure 4b. Measured fatigue crack growth rates for the 2024-T3 and 2198 alloys were similar in the threshold and mid-range regions. The 2198 alloy displayed longer fatigue life in all grain orientations than the 2024-T3, as shown in Figure 4c. The next phase of testing will consider compression, lap-joint fatigue, and corrosion properties. (Continued Airworthiness)

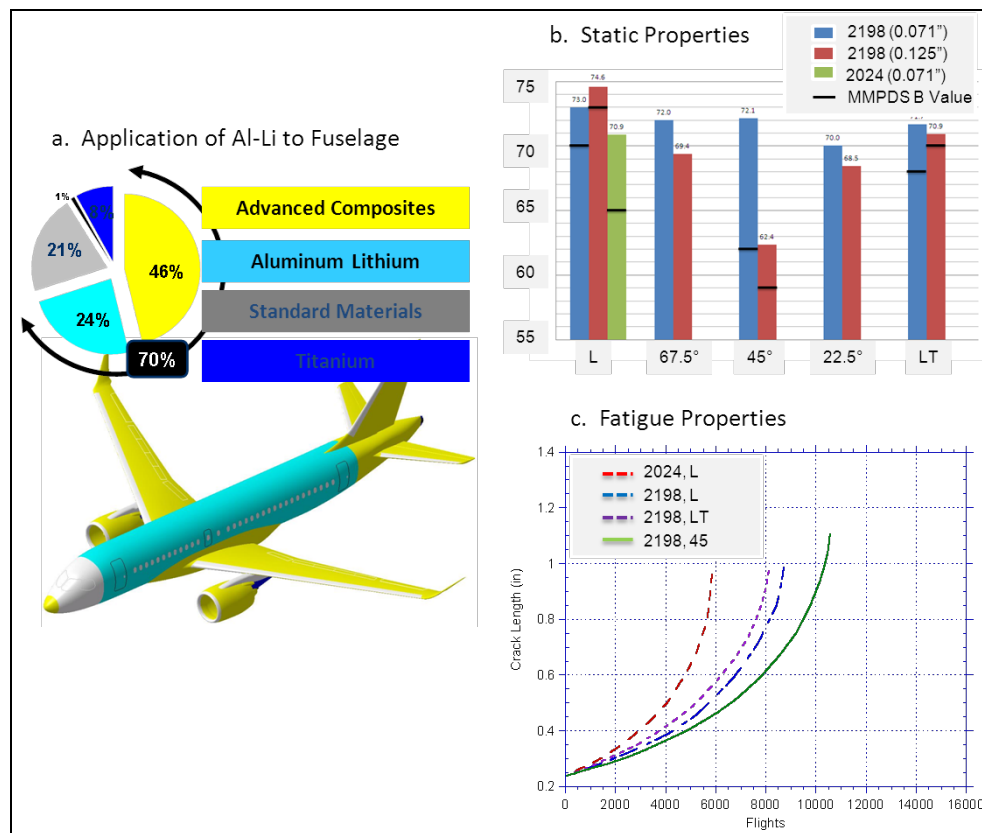


Figure 4: Interim Test Results for the Assessment of Aluminum-Lithium as a Primary Structure

The Effect of Pressure and Oxygen Concentration on the Burning Rate of Materials:

Understanding the behavior of burning materials at reduced pressure is important because aircraft depressurization is an approved procedure employed in freighter aircraft to suppress an in-flight cargo compartment fire. In addition, during an enclosure fire, the concentration of oxygen may become depleted, affecting the characteristics of the fire. Thus, the FAA undertook a study to examine and attempt to quantify the effect of pressure (altitude) and oxygen concentration on the burning rate of a material.

The material selected for the study was polymethyl methacrylate (PMMA), because it is readily combustible and burns relatively uniformly. Researchers conducted experiments in a 10 cubic-meter pressure vessel, capable of reaching pressures as low as 0.1 atmosphere. The PMMA flammability was characterized by the burning rate and the time to ignition. The FAA conducted tests at pressures from 0.18 to 1.0 atmosphere, with oxygen concentrations from 12 to 21 percent, and applied external heat fluxes from 10 to 72 kW/m². Researchers developed a simple analytical model to compare with the experimental results.

The experimental measurements and observations revealed the effect of pressure and oxygen concentration on the burning characteristics of PMMA. As the pressure decreased, the height of the flame diminished and the color of the flame changed from bright yellow at atmospheric

pressure to a dim blue at lower pressures, as shown in Figure 5. The results also showed that the steady burning rate decreased with pressure, a decrease that was more evident at lower values of the external heat flux. On the other hand, a reduction in pressure causes the sample to ignite earlier, apparently due to convective heat losses that decrease as researchers lowered the pressure, causing higher PMMA surface temperatures. For all pressures tested, the burning rate decreased when researchers decreased the oxygen concentration.

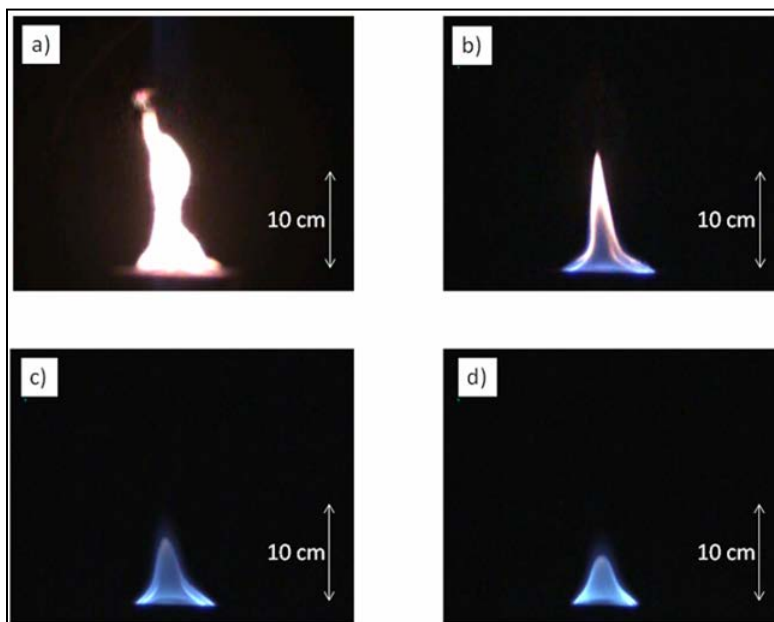


Figure 5: Effect of Pressure on Flame

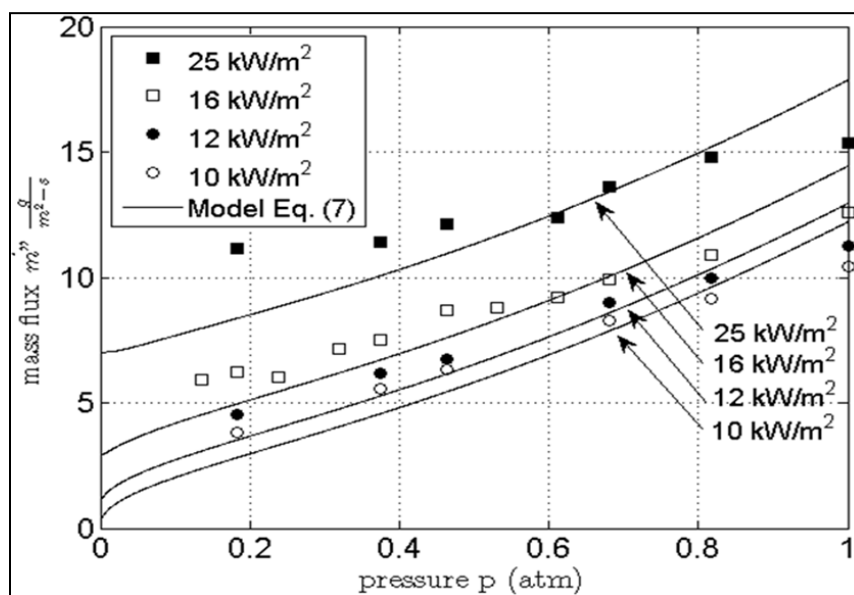


Figure 6: Comparison of Experimental and Theoretical Burning Rates

The FAA compared the experimental results with the simple analytical model predictions, as shown in Figure 6. The research shows that the model predicts the dependency of the burning rate on pressure reasonably well at low external heat fluxes, up to about 25 kW/m². The model clearly under-predicts the burning rate at higher external heat fluxes where the experimental data show little effect of pressure. Further, the model indicated that the burning rate was proportional to the product of the square root of pressure and oxygen concentration. Using this product, a simple relationship was derived for the measurements made with all PMMA samples burned at different pressures, oxygen concentrations, and external heat fluxes, except at the higher heat fluxes that dominate the burning rate. (Fire Research and Safety)

Cockpit Visibility Impairment from an Electronic Flight Bag (EFB) with Lithium Batteries in Thermal Runaway:

The FAA conducted tests on board an operational Boeing 737 aircraft to evaluate the potential safety hazard resulting from the thermal runaway failure of the lithium batteries in an Electronic Flight Bag (EFB). EFBs are electronic devices used to replace the paper materials typically found in the pilot's flight bag. EFBs are divided into three classes:

- Class I – Portable electronic device (PED), commercial-off-the-shelf (COTS) equipment used as loose equipment and stowed during portions of flight. There is no active charging on board the aircraft.
- Class II – PED, can be COTS equipment, mounted and connected to aircraft power during flight for use and charging.
- Class III – Considered installed equipment; these are not PED or COTS equipment, but rather are pieces of equipment built and tested specifically for aircraft EFB use. They connect to aircraft power during flight for use and charging.

Class I and II EFBs are considered PEDs that are not subject to airworthiness standards; however, the mounting and charging connection hardware used for the installation of a class II EFB is required to be airworthy. Class III EFBs are subject to airworthiness standards, as they are considered installed equipment. The primary concern is the resulting fire and smoke hazards should one of the lithium-ion (Li-ion) batteries installed in these units fail and experience thermal runaway, a failure causing rapid increases in temperature, significant smoke production, and, at times, explosion or rocketing of the battery cell.

To examine this potential safety hazard, researchers replaced one or two individual battery cells (depending on the test criteria) in a COTS laptop with a small cartridge heater. This small heater used replicated a single battery cell going into thermal runaway, causing adjacent cells within the 9-cell, 7.2 Ah Li-ion battery pack to subsequently go into thermal runaway. Researchers installed this laptop in the cockpit of the Fire Safety Branch's Boeing 737 test aircraft, which they instrumented with thermocouples, gas sampling probes, smoke meters, and video cameras to examine the results of the battery failure. To protect the 737 test article, researchers fire-hardened the cockpit. In addition, investigators immediately disbursed Halon 1211 into the cockpit to extinguish the flames at any sign of fire, which became a common occurrence during testing. Therefore, the focus of these tests was the smoke hazard resulting

from the propagation of thermal runaway in the lithium batteries inside an EFB when extinguishing a fire.

Despite a high ventilation rate of one air exchange per minute within the cockpit, test results revealed that a typical COTS Li-ion battery could pose a significant smoke hazard within the flight deck environment. At times, the initial battery event occurred without warning (i.e., with no visible smoke or audible event prior to failure). At one point during testing, the battery cells failed vigorously with enough pressure to force open the unlatched cockpit door. However, the most striking safety hazard was the volume and density of smoke emanating from the failed battery cells. During a test in which only four of the nine battery cells went into thermal runaway, the installed smoke meter recorded greater than 10 percent light obscuration/ft. for a period of greater than five minutes and a peak value of greater than 50 percent light obscuration/ft., resulting in severe lack of visibility within the flight deck. Figure 7 shows the cockpit view during testing, where (a) is the view prior to the first battery cell failure, (b) is the view at initial battery cell failure, (c) is the view at 27 seconds after initial failure, and (d) is the view 1 minute and 45 seconds after battery failure. (Fire Research and Safety)

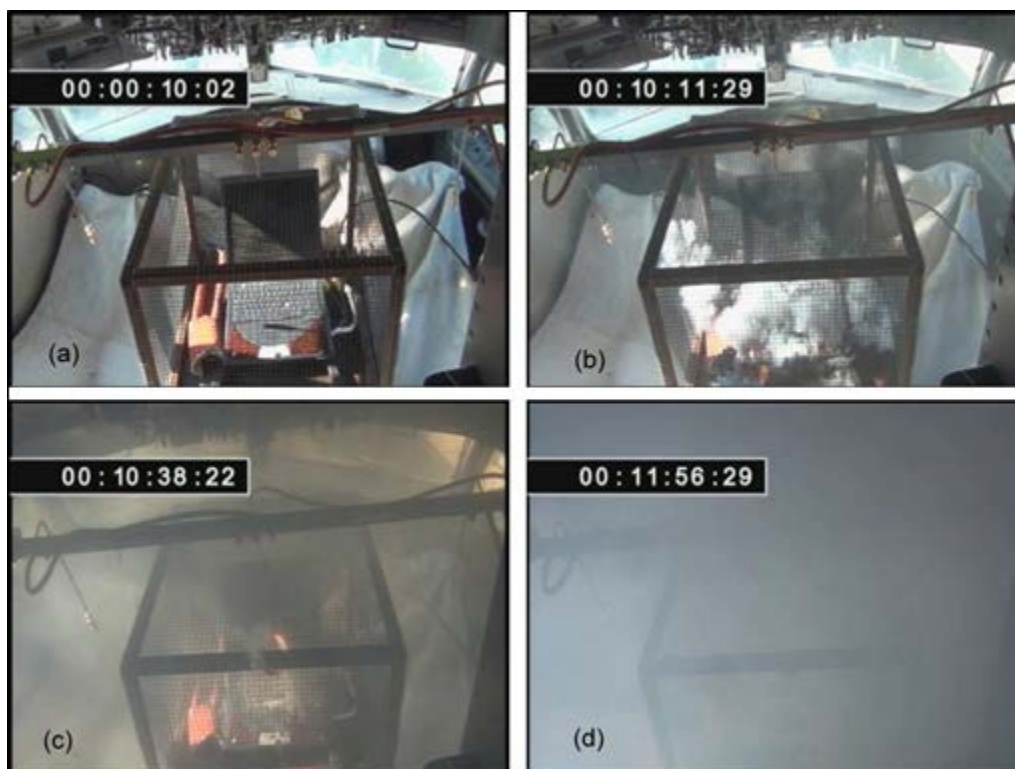


Figure 7: Cockpit Visibility Impairment during Testing of Thermal Runaway of an EFB with Lithium Batteries

Development of a Fire Test for Magnesium Seat Structure:

In recent years, magnesium alloys have been proposed as a substitute for aluminum alloys in aircraft seat structure and other applications due to the potential for weight savings. Although magnesium alloys are routine in the construction of non-cabin aircraft components, FAA policy

described in Technical Standard Order TSO-C127 *Rotorcraft and Transport Airplane Seat Systems* has prohibited the use of magnesium alloys in aircraft seats for decades. The FAA's central concern regarding the use of magnesium and its many alloys in the cabin is flammability. The current flammability regulations do not address the potential for using a flammable metal in large quantities in the cabin, such as in seat structures. However, recent developments in materials technology have shown that different magnesium alloys have differing susceptibility to ignition. Yet, magnesium remains a material that, once ignited, is very challenging to cope with using fire extinguishers currently available on commercial aircraft. Therefore, the FAA undertook research to determine whether manufacturers could safely use magnesium alloys in aircraft seat structure and, if shown to be safe, develop an appropriate flammability test method to ensure fire-safe seat structure.

The FAA conducted a preliminary assessment of magnesium alloy flammability using a laboratory-scale test rig. The test rig consisted of an oil-fired burner to simulate a post-crash jet fuel fire as well as a mounting mechanism used to secure and expose representative test samples. Investigators evaluated test samples consisting of several blends of magnesium alloy. One of the samples was a prototype alloy containing rare earth elements to minimize flammability and tests indicated a large difference in flammability between the various samples evaluated. Magnesium alloys, WE-43 and Elektron-21, both showed an outstanding resistance to ignition when compared to the more conventional alloys, such as AZ-31. Additional laboratory-scale tests evaluated the performance of handheld fire extinguishers against these same alloys when ignited.

Realistic full-scale testing of these alloys also provided useful information into the feasibility of using such materials in the primary components of aircraft coach seating. During the testing, the FAA determined that the prototype WE-43 material produced minimal quantities of toxic and flammable gases during a five-minute fire exposure. The full-scale tests confirmed that certain new magnesium alloys were capable of use in the aircraft's cabin without producing additional hazards during a simulated post-crash fire event. These tests paved the way for the development of a laboratory-scale flammability test for magnesium alloys used in the construction of aircraft seats.

Researchers used an oil-fired burner, configured according to the current test parameters for seat cushion flammability testing, as the basis for the new flammability test. During initial trials, researchers mounted bar-shaped test samples horizontally in front of the burner flames, and exposed until melting occurred. It was necessary to bring the magnesium alloy samples to their melting point in order to induce any ignition. The FAA tested various thicknesses and alloys, yielding an array of data on the melting times, time to ignition, and duration of burning following burner removal. These were determined to be the most important flammability factors during the tests. The goal was to devise a condition in which the alloy WE-43 would ignite at approximately two to three minutes of exposure, and subsequently self-extinguish within 90 seconds of the burner flame's removal. This behavior would mimic the full-scale fire test results obtained using this particular alloy. Although this result was initially achieved with a truncated cone sample, additional tests proved the inconsistency of this configuration. Investigators conducted subsequent trials on upright hollow cylinders as well as numerous other shapes and sizes of samples in an effort to produce a repeatable and representative test condition. Researchers ultimately narrowed down the sample configurations to a horizontal bar and an

upright hollow cylinder. Additional testing led to the selection of the horizontal bar as the configuration of choice, shown below, based on its relative ease of fabrication and having similar characteristics witnessed during full-scale fire tests. Follow-on tests are underway to perfect the test procedure, and finalize test conditions and pass/fail criteria. (Fire Research and Safety)



Laboratory-Scale Flammability Test on a Magnesium Alloy Bar Sample

Evaluation of Computational Fluid Dynamics Models for Smoke Movement in Cargo Compartments:

To ensure aircraft fire safety, Federal Aviation Regulations mandate the use of certified smoke and fire detection devices in aircraft cargo compartments. These systems, although successful at fire detection, are prone to detect airborne particles not associated with fire, hence, have high false alarm rates. Research suggests that only one in every hundred alarms is due to a real fire source. False alarms lead to unnecessary evacuations, flight delays, and diversions from intended flight paths, and bring additional safety and cost concerns. Moreover, the certification process requires not only ground tests but also in-flight tests that are both expensive and time consuming. Therefore, cost considerations limit the number of fire scenarios that can be employed to demonstrate that detector response time is compliant with regulatory requirements. In order to improve the reliability of detection systems and to reduce the number of necessary tests for certification, it is critical to have a better understanding of fire and smoke behavior in cargo compartments. Although experimental research efforts are ongoing for this purpose, because of the scenario-specific nature and complexity of the problem, it is also important to use available numerical modeling methods.

The focus of this study was to assess the predictive abilities of computational fluid dynamics (CFD) tools for the transport of smoke and hot gases due to a possible fire source in a cargo

compartment. The FAA chose the Fire Dynamics Simulator (FDS), developed by the National Institute of Standards and Technology, over many other open-source candidates, particularly for its fast turnaround time and robustness. FDS simulations were compared with an extensive set of data collected from FAA fire tests that span four test cases in two cargo compartments, namely a Boeing 707 and a McDonnell Douglas DC-10. The selected metrics for the comparison were prediction of temperature, light transmission, and concentration of CO and CO₂ in the first three minutes of test initiation. Figure 8 is a schematic of the model geometry of the cargo compartment, and Figure 9 shows the predicted smoke behavior in the cargo compartment.

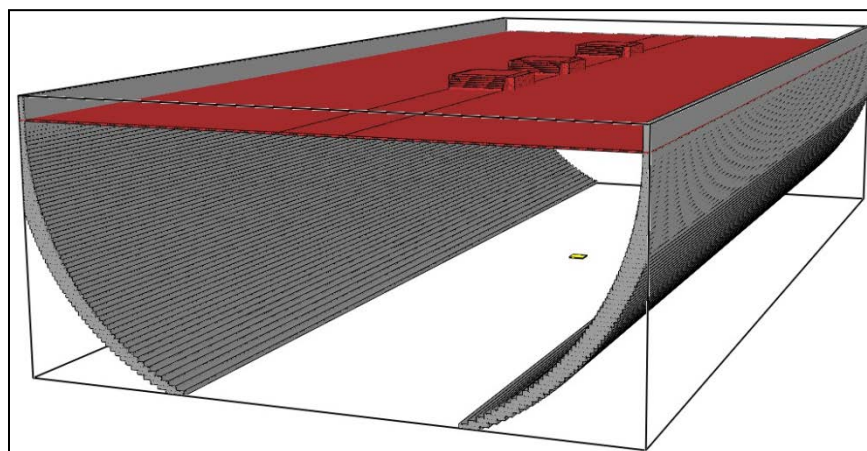


Figure 8: B-707 Cargo Compartment Simulations – Model Geometry

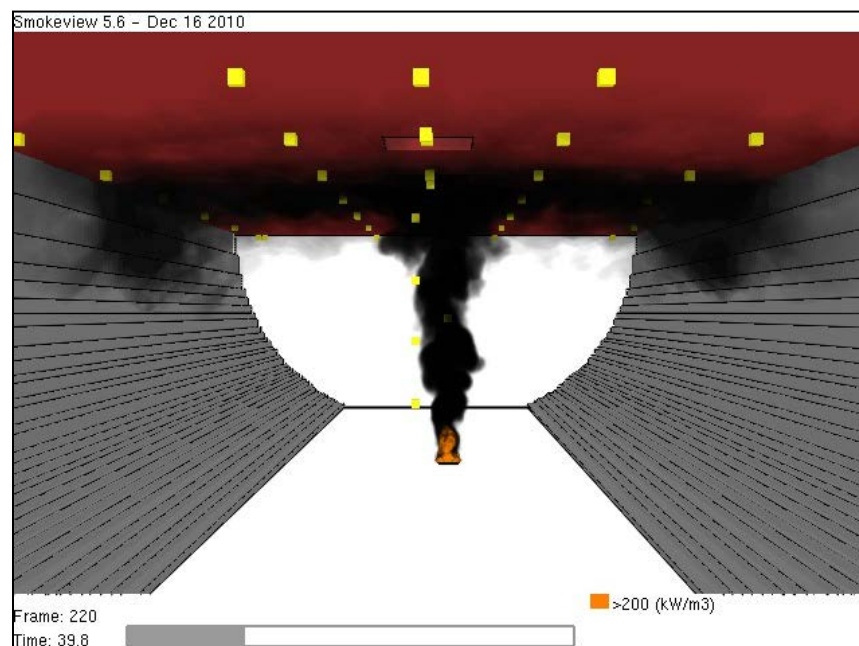


Figure 9: B-707 Cargo Compartment Simulations – Smoke Predictions at 40 seconds into the Test

For the test cases studied, CFD is proven a powerful tool, producing results that are in good agreement with the available test data. For one of the fire scenarios studied, Figure 10 and

Figure 11 display the contour plot comparisons of measured and predicted ceiling gas temperatures, respectively. Figure 12 and Figure 13 show the time variation comparisons of CO concentrations and light transmissions due to visible smoke obscuration, respectively.

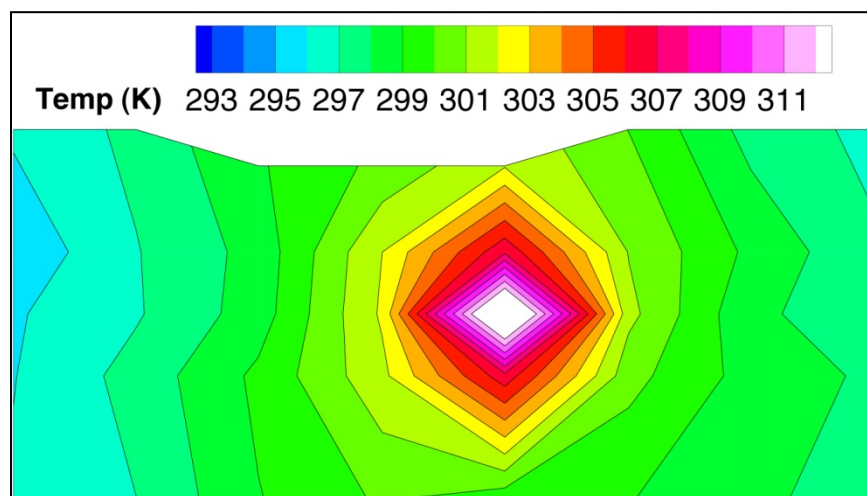


Figure 10: B-707 Cargo Compartment Simulations: Contour Plots of Measured Ceiling Gas Temperatures at 90 seconds into the Test

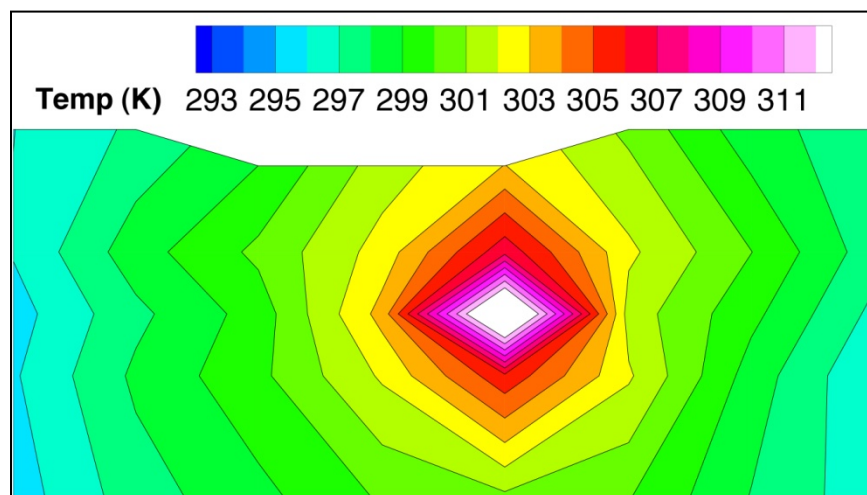


Figure 11: B-707 Cargo Compartment Simulations: Contour Plots of Predicted Ceiling Gas Temperatures at 90 seconds into the Test

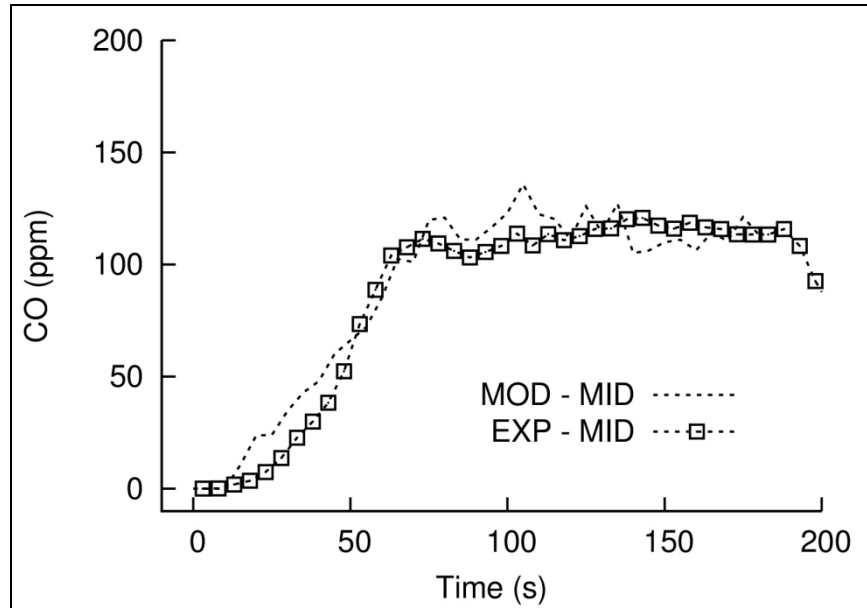


Figure 12: B-707 Cargo Compartment Simulations: History of Carbon Monoxide Concentration at Mid-ceiling Gas Analyzer

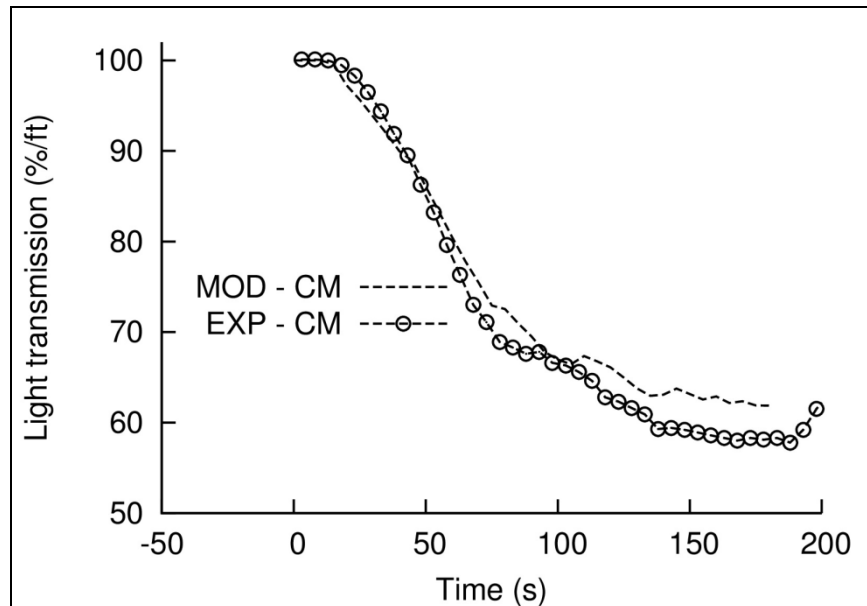


Figure 13: B-707 Cargo Compartment Simulations: History of Light Transmission at Mid-ceiling Beam Detector

Agreement between model predictions and experimental data demonstrates the potential of CFD fire modeling, and encourages its use as a tool to complement experimental research efforts in developing enhanced detection algorithms and optimal location of detectors. The current study established the main areas of model limitations and identified possible improvements to the experimental set-ups. The overarching benefits include the use of fire modeling as a means to analyze risk and vulnerability of the existing systems in addition to the effectiveness of future modifications dictated by the aircraft fire-safety requirements. (Fire Research and Safety)

The Impact of Discharged Extinguishing Agent in the Flight Deck and Cabin on Human Safety:

The safe-use guidance for hand extinguishers in AC 20-42D *Hand Fire Extinguishers for Use in Aircraft* provides discharge limits for halocarbon extinguishing agents that are safely below the adverse effect level. Peak arterial blood concentrations predicted for an exposed person should not exceed a target arterial blood concentration, which the FAA considers the threshold for safe use. Using a simple kinetic model developed by the FAA Fire Safety Team, arterial blood concentration histories were determined from Halon 1211 gas concentration histories. The model has proven to be in good agreement with Physiologically Based Pharmacokinetic Modeling.

The safe use guidance in AC 20-42D is based on the assumption of instantaneous perfect mixing in a ventilated aircraft cabin. Actual halocarbon gas and arterial concentrations may be lower than predicted at the nose level of a seated or standing passenger due to stratification of the heavier-than-air agent and exhaust at the floor-level air return ducts, or higher than predicted at locations in the aircraft near where the agent is discharged.

A stratification/localization multiplication factor can be applied to the perfect mixing concentration to increase the allowable AC-20-42D safe use weight of agent to account for stratification/localization based on the position that a reasonable mobile person would be located at the time of discharge. This would allow the use of effective extinguishers that might otherwise be prohibited because of safety concerns. For example, higher Halon 1211 extinguisher charge weights than those based on peak arterial perfect mixing concentrations are expected to be safe due to a long history of safe use of Halon 1211 extinguishers in small compartments.

This study characterized Halon 1211 distribution in time and space, determined the arterial concentration histories from the agent gaseous concentration histories, and determined the stratification/localization multiplication factors for cabin and flight deck Halon 1211 discharges for a particular B-737 configuration. The test targets were selected after considering the most probable fire sources based on a history of fire occurrences. Cabin discharges were directed at an overhead exit light at the aft end of the cabin seating area. Discharging the extinguisher near the far end of the cabin should provide the highest localized concentrations. Flight deck discharges were directed at the copilot's window heater and lower instrument panel.

The test setup for the flight deck window heater discharge test appears below as well as a chart of gas concentration histories in Figure 14. The perfect mixing gas concentration histories were calculated based on the weight of agent discharged and the air change time of the compartment, taking into account the cabin air leakage rate, which was determined experimentally.



Firefighter Directing Extinguisher at Copilot's Window Heater in
FAA B-737 Test Aircraft

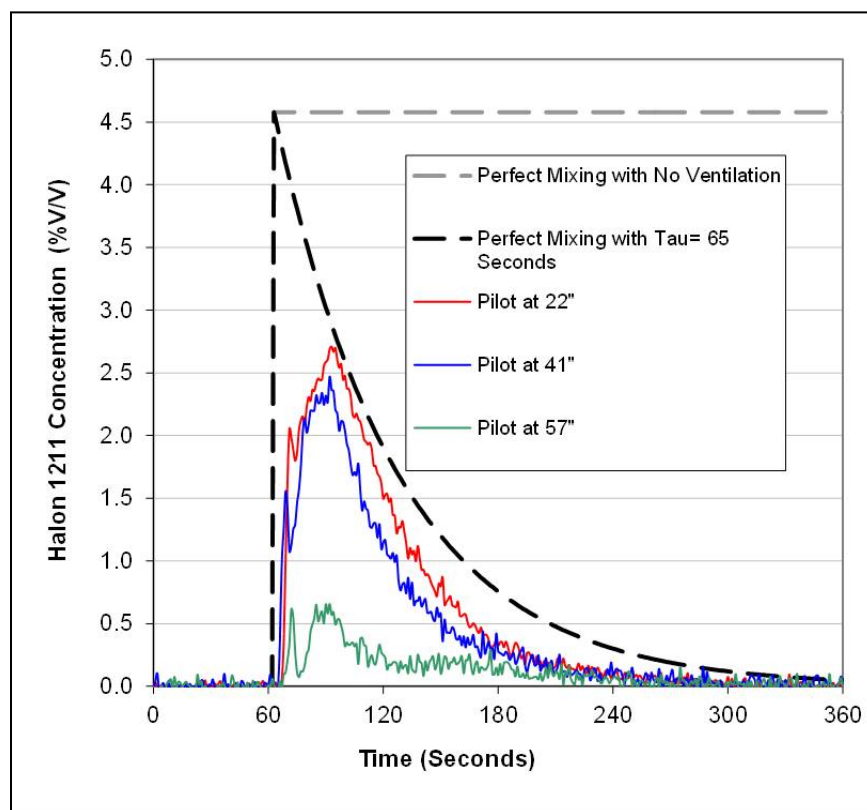


Figure 14: Halon Concentration versus Time- Discharge Directed
at Copilot's Window Heater

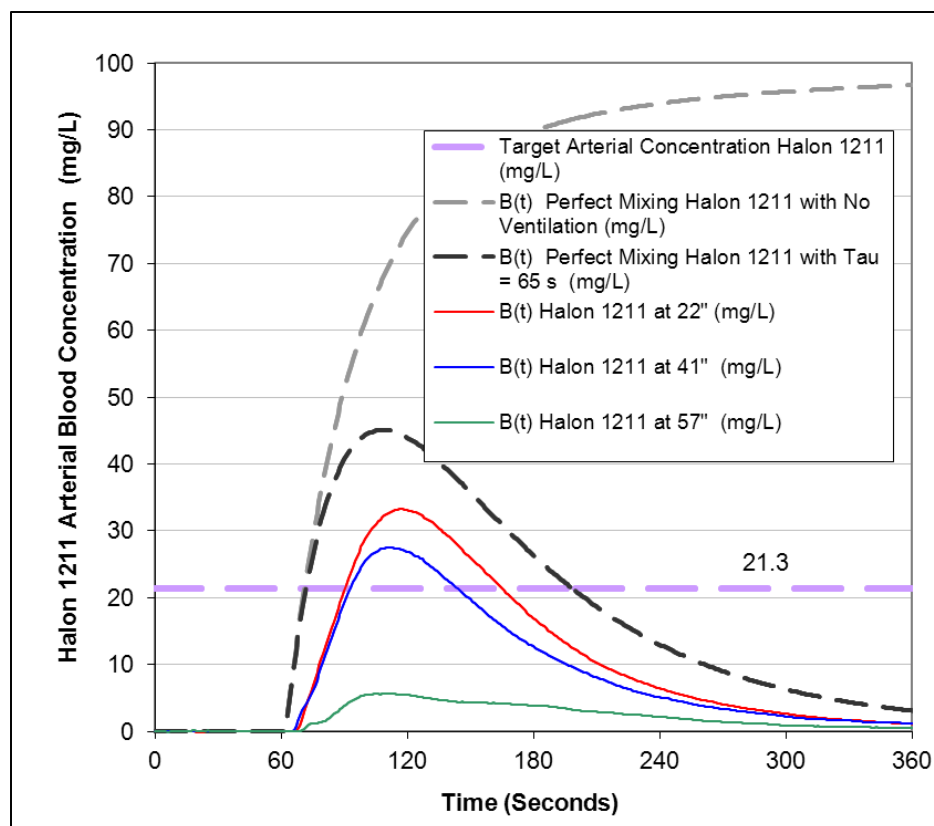


Figure 15: Halon Arterial Blood Concentration versus Time-
Discharge Directed at Copilot's Window Heater

The resultant arterial blood concentration histories, obtained using a simplified kinetic model, appear in Figure 15. The ratio of the predicted peak arterial blood concentration, obtained from assuming perfect mixing in a ventilated compartment to the test-based predicted peak arterial blood concentrations, provides a stratification/localization multiplication factor for each test and each gas sampling position. Considering this data, one can select a multiplication factor that can be applied to the currently recommended maximum Halon 1211 concentrations to provide higher safe concentrations of Halon 1211. The resulting multiplication factors appear in Figure 16 and Figure 17. For example, the multiplication factor for a seated pilot (41") was 1.6 when the agent was discharged at a window heater. (Fire Research and Safety)

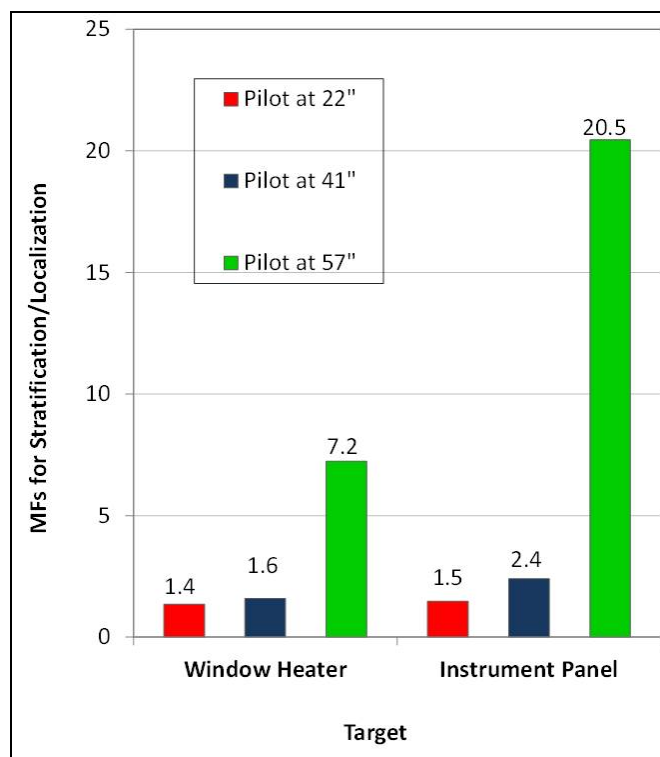


Figure 16: Multiplication Factors for Stratification/Localization for B-737 Flight Deck Tests

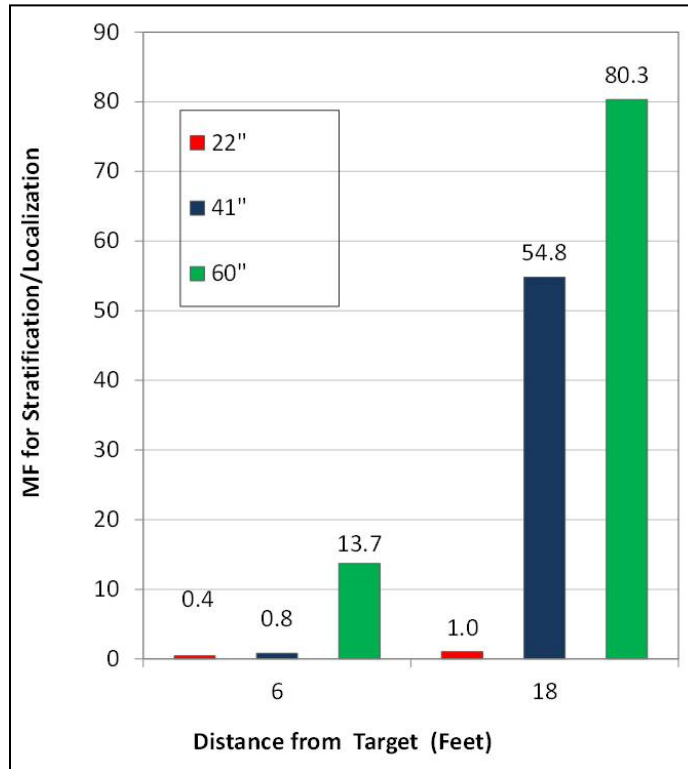


Figure 17: Multiplication Factors for Stratification/Localization versus Distance from Target for B-737 Cabin Tests

Preliminary Full-Scale Fire Tests with Bulk Shipments of Lithium Batteries:

The FAA has conducted a considerable amount of research to characterize the flammability hazard associated with the use, handling, storage, and shipment of lithium-ion (rechargeable) and lithium metal (non-rechargeable) batteries. The results of a single cell induced into thermal runaway have been well documented, including case temperature, auto ignition temperature, flammable electrolyte ignition, molten lithium, and explosive pressure. The FAA has explored the effect a single cell in thermal runaway has on adjacent cells in a bulk shipment cardboard box. Researchers have determined that a single cell in thermal runaway produces enough heat to cause other nearby cells within the shipping box to enter thermal runaway, too. This process has been shown to propagate to all cells within the box as well as to adjacent boxes of cells, as shown in a test with 3, 100-cell boxes. Halon 1301, the fire suppressant used in all passenger-aircraft cargo compartments is ineffective in stopping the propagation of thermal runaway in lithium-ion and metal cells, though it does suppress the open flame from a lithium ion battery and spread to other combustibles. It is ineffective against a flaming lithium metal battery.

This research has been the basis for banning the bulk shipment of lithium metal batteries on passenger aircraft as well as two Safety Alerts for Operators: “09013: Fighting Fires Caused By Lithium Type Batteries in Portable Electronic Devices” and “10017: Risks in Transporting Lithium Batteries in Cargo Aircraft”.

Regulations permit the bulk shipment of lithium-ion cells on passenger aircraft with Halon 1301 cargo-compartment fire suppression systems and permit the bulk shipment of both ion and metal cells on cargo aircraft. Investigators suspect the involvement of lithium batteries in recent accidents resulting in the loss of two Boeing 747 cargo aircraft. As such, the FAA has identified the need to characterize the flammability hazard associated with a large shipment of lithium batteries in a realistic aircraft environment. To this end, the FAA Fire Safety Branch is instrumenting a Boeing 727 freighter with the intent of running full-scale fire tests with lithium batteries. Bulk shipments of lithium batteries can number in the tens of thousands. For the purposes of these tests, researchers have chosen a fire size of 5,000 cells.

The FAA has conducted two tests in an outdoor setting to determine the severity of the fire prior to conducting similar tests within the Boeing 727. Researchers have installed thermocouple instrumentation to measure the peak temperatures and rate of propagation. The first test consisted of 5,000 lithium-ion 18650 cells in 50, 100-cell boxes. The second test consisted of 4,800 lithium metal SF123A cells in 12, 400-cell boxes. In each test, researchers removed a single cell from a centrally located box at the bottom of the stack and replaced it with an electric cartridge heater of similar dimensions and whose temperature profile closely matches a cell in thermal runaway. Researchers initiated the tests by energizing the heater.

- 5,000 lithium-ion cell test results: Much like the smaller-scale tests, the spread of thermal runaway proceeded to other batteries, gradually speeding up as the fire size increased. Many cells exploded, rocketing as far as 133 feet from the site of the fire. Peak temperature measured 4 inches above the battery stack, was 1,400° F. The

maximum temperature within the battery stack peaked at 1,668° F. The duration of the fire from initial smoke observance to final flame out was 1 hour, 5 minutes.

- 4,800 lithium metal cell test results: Again, much like the smaller-scale tests, the spread of thermal runaway propagated from cell to cell, and box to box. However, the rate of propagation increased dramatically as the fire size increased. Nearly all of the cells remained in place during the fire, fusing together in the extreme heat. Peak temperature measured four inches above the battery stack was 1,993° F and 2,009° F within the battery stack. The duration of this test was in stark contrast to the lithium-ion battery test, 17 minutes from first smoke to final flame out.

The FAA conducted a third test to evaluate the effectiveness of water as an extinguishing agent on lithium metal battery fires. The test consisted of a stack of 400 lithium metal SF123A cells, initiated with a cartridge heater. The fire was allowed to progress to a high intensity, at which time water was sprayed from 4, 15-gallon per minute nozzles. The water immediately extinguished the open flame and rapidly cooled the battery stack. The water spray continued until all thermocouples indicated the batteries were cooled, about 5 minutes. Researchers monitored the temperature, which showed a gradual increase, upon which they again applied water. After three applications of water, the battery pack remained cool and researchers considered the fire extinguished.

The FAA is applying the results of these tests to the design of the full-scale tests they will conduct in the Boeing 727 freighter. (Fire Research and Safety)



5,000 Lithium-ion 18650 Cell Fire Propagation Test

A Statistical Model of Fire Test Results:

Aircraft cabin materials must meet regulatory requirements for fire safety established by the FAA. The tests used by the FAA to determine the fire safety of materials and products used in aircraft measure, either directly or indirectly, the spread of flame over a solid combustible surface under standardized conditions. These conditions may include a particular sample orientation with respect to gravity, air velocity, source of ignition, or imposed heat flux to force the sample to burn. What the FAA measures in the bench-scale fire test is the duration, extent, or velocity of burning, or the rate at which heat is released during burning. The FAA then assigns a pass/fail rating to the material based on performance criteria derived from full-scale aircraft fire tests. In principle, the flame spread or burning rate of the sample, and hence the outcome of the bench-scale fire test, is determined by the test conditions and the fire properties of the specimen. In practice, fire test results also depend on the skill of the operator, the condition and calibration of the equipment, and anomalous physical behaviors of samples, such as melting, dripping, swelling, deformation, incomplete combustion, edge effects, thickness variations, off-gassing, and so on. Consequently, the FAA must conduct numerous fire tests requiring many kilograms of cabin material to establish compliance with the regulations. The uncertainty in the outcome of pass/fail fire tests, and the relative importance of a material fire property to this outcome, make it difficult or impossible to establish a particular (threshold) value of a fire property that can be accurately measured in a small-scale test and subsequently used to screen new fire safe materials for development or used for quality control of production cabin materials.

To this end, the FAA developed a statistical methodology using a well-known model for surface flame-spread on a vertical sample that was rewritten in terms of thermal combustion (fire) properties of the materials measured in the FAA Microscale Combustion Calorimeter (MCC) using milligram samples. This allowed the pass/fail criterion—maximum flame spread rate or extent or burning—for the regulatory tests to be expressed as a flame spread criterion in terms of properties easily measured in MCC tests. Researchers evaluated several thermal combustion properties as explanatory variables for two pass/fail fire tests. The fire tests included a heat release (burning) rate test used by the FAA for large area cabin materials (FAR 25 HRR) and an upward flame spread test used by Underwriters Laboratories as a voluntary standard for flammability of plastics (UL 94 V-0) used in electrical and electronic applications. Researchers conducted fire tests on hundreds of research and commercial polymers, flame retardant plastics, composites and adhesives used in aircraft. Moreover, the FAA measured several thermal combustion properties for each sample in the MCC before fire testing.



FAA Part 25 Heat Release Rate Test for Cabin Materials



Underwriters Laboratories Vertical Flame Test for Flammability of Plastics



Milligram-Scale Fire Test in the FAA Microscale Combustion Calorimeter

The FAA analyzed fire test and MCC data by calculating the fraction of passing results for each fire test over a small range of MCC properties. This gives the likelihood (probability) of passing a fire test for an average value of the thermal combustion property; that is, it gives a probability distribution with the thermal combustion property as the explanatory variable. This empirical probability distribution, shown in Figure 18 and Figure 19, could be fit with the flame-spread criterion, using two adjustable parameters. Circles are experimental data, and solid lines are fits of the flame spread criterion to the experimental data. Research determined that the flame-spread criterion could describe the empirical probability distribution using some, but not all, of the thermal combustion properties as explanatory variables. The MCC thermal combustion properties showing the best predictive capability were the heat of combustion of the sample (Figure 18) and the heat release capacity (Figure 19). Researchers can then use the resulting parametric equation, shown as solid lines in Figure 18 and Figure 19, to calculate the likelihood of passing the UL 94 vertical flame test or FAR 25 HRR test for any material for which thermal combustion properties can be measured in the MCC. (Fire Research and Safety)

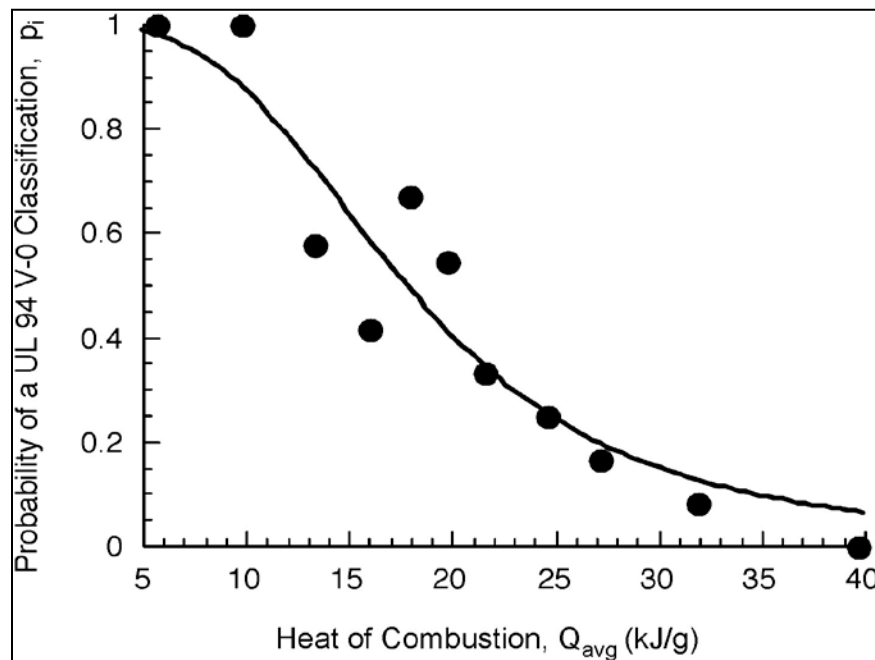


Figure 18: Plot of the Probability of Obtaining a V-0 Rating in UL 94 Vertical Flame Test versus the Heat of Combustion of the Material Measured in the FAA Microscale Combustion

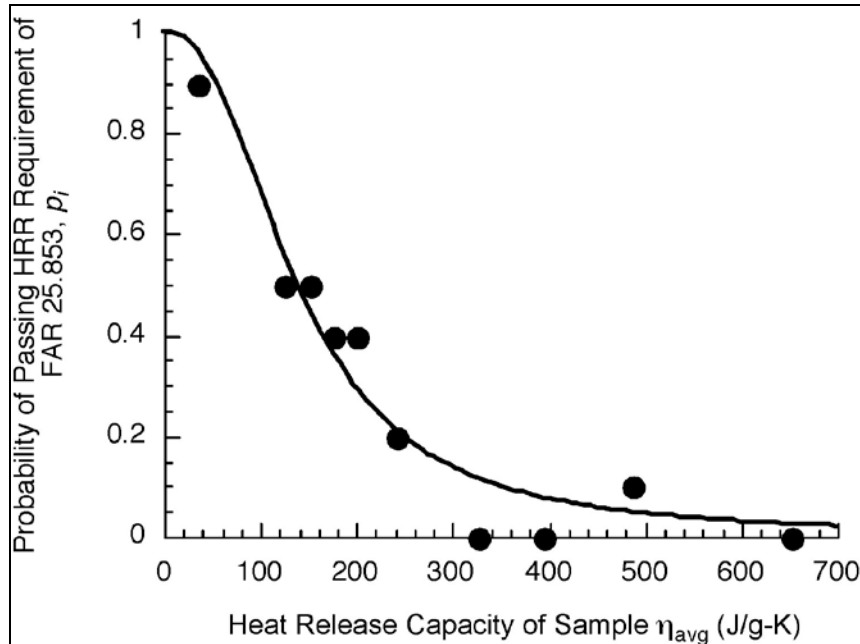


Figure 19: Plot of the Probability of Passing the FAR 25 Requirement for the Heat Release Rate of Cabin Materials versus the Heat Release Capacity of the Material Measured in the FAA Microscale Combustion Calorimeter.

An Evaluation of Methods to Train Visual Approach Skills:

Although performing a visual approach is relatively common, even in commercial operations under Instrument Flight Rules (IFR), aviation trainers have expressed concerns that pilots continue to have difficulty executing visual approaches. In response, researchers from the University of Central Florida and George Mason University investigated the applicability of using different types of perceptual and conceptual training to improve pilots' assessment of appropriate glide slope during visual approaches (i.e., the angle of approach that pilots should maintain to land the aircraft safely). Researchers developed and investigated, through a series of seven studies, two prototype-training methods: five laboratory studies with 498 undergraduate students and two field studies with 106 experienced pilots (64 major airline pilots and 42 regional airline pilots). Based on the results, the researchers published a report of their findings and a guidelines document for practitioners containing best-practice recommendations for visual approach training. In general, there should be an emphasis in visual approach training when skills particular to a specific maneuver are most valuable. The guidelines document also lays out a preferred sequence for practicing visual approaches using training aids, flight training devices, and simulators, and specifies the types of conditions that should vary as pilots improve their visual approach skills. Finally, in addition to the applied contribution, this research helped bridge the theory/application gap by validating, in an applied aviation task, a model of perceptual learning that had only previously been used with artificial laboratory tasks. The findings and training guidelines provide critical scientific and technical information that will be beneficial to FAA regulators, training practitioners, pilots, and others who seek methods to improve training

of underemphasized flight skills, such as visual approaches. (NextGen – Air Ground Integration Human Factors)



Simulator used for Visual Approach Training

Cockpit Display of Traffic Information (CDTI) Based on Automatic Dependent Surveillance-Broadcast (ADS-B):

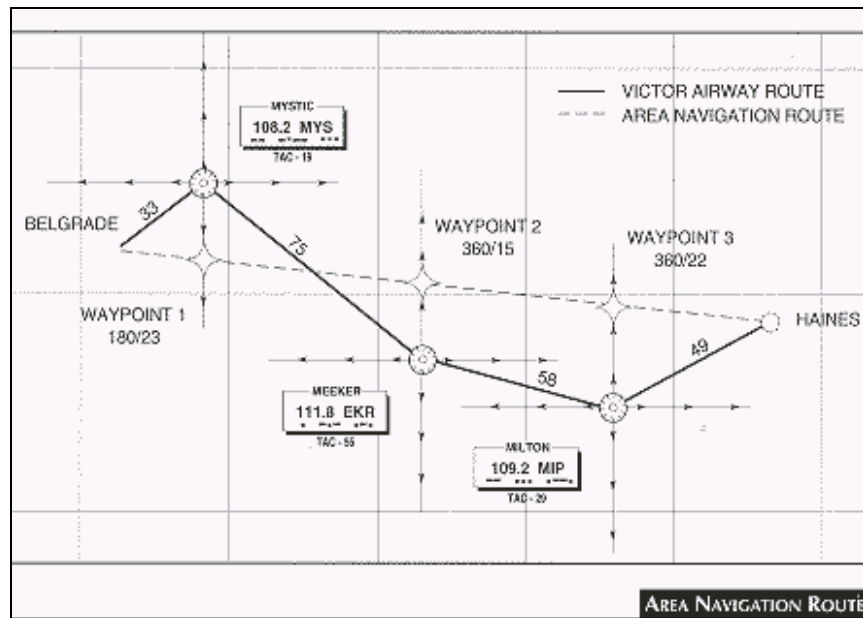
The FAA is identifying human factors issues associated with the use of a Cockpit Display of Traffic Information (CDTI) based on Automatic Dependent Surveillance-Broadcast (ADS-B). This research concerns four main areas: (1) conducting a CDTI industry survey, (2) examining CDTI display management, (3) identifying human factors issues associated with CDTI alerting, and (4) providing support for ongoing CDTI operational evaluations sponsored by the FAA Surveillance Broadcast Services Program Office. Researchers used several approaches to gather information for this research program, including discussions with industry representatives, literature reviews, and participation in RTCA Special-Committee 186. They produced three key documents in FY 2012. The first was a draft of human factors considerations and recommendations associated with alerting applications that researchers can apply in assessing new systems, including recommendations regarding the operational need for an alert, the salience of alerts, and alert location. The second report provides recommendations for data collection for operational evaluations of CDTI. The FAA expects the results of this work to assist the Office of Aircraft Certification in the evaluation of CDTIs and ADS-B technology as well as identify issues the FAA needs for the successful implementation of ADS-B. The third report describes a symbology study conducted to understand which traffic symbols pilots perceive to be useful and intuitive when displayed on a surface moving map. Researchers intend for the results to support the development of RTCA DO-317 *Minimum Operational Performance Standards (MOPS) for Aircraft Surveillance Applications System (ASAS)*. (Flightdeck/Maintenance/System Integration Human Factors)



ADS-B/CDTI

Human Factors Guidance for the Use of NextGen Instrument Procedures:

This effort supports the FAA's transition to NextGen by identifying human factors issues associated with implementing performance-based navigation (PBN) instrument procedures based on area navigation (RNAV) and required navigation performance (RNP) as well as by providing recommendations to promote easier and more reliable use of these NextGen procedures. Since new procedures may result in increased visual complexity of charts, which in turn could increase pilot workload and the potential for error, the present study aimed to produce recommendations that would ultimately help to reduce susceptibility to errors by appropriately qualified pilots. Through consultation with subject matter experts, review of relevant scientific literature and available operational information, and completing a study of alternative chart formats, the Human Factors team developed recommendations to improve the usability of aeronautical charts for PBN. The Human Factors team also demonstrated the chart format study to FAA instrument procedure designers and obtained their feedback on the study method. Results will enable the FAA to modify, update, and improve related guidance documents (e.g., FAA Orders in the 8260 series, FAA Order 8900.1, AC 120-76, and others). Ultimately, the potential outcome of this research will be a reduced likelihood of pilot error and improved operational implementation of PBN-based airspace procedures. (Flightdeck/Maintenance/System Integration Human Factors)



Area Navigation Chart

Symbology Standard:

In FY 2012, researchers responded to the need of acquisition specialists in the Air Traffic Organization to mitigate the differences in the design of symbols used across legacy and new air traffic control (ATC) systems and upgrades. Researchers produced a standard for the creation, use, structure, and content of symbols, icons, markings, legends, text, and other constructs conveying information on ATC displays. Developed in accordance with the FAA Standard for Developing Standards, the new FAA standard will apply it as a requirements document for future ATC systems acquisitions. The standard focuses on the information conveyed by the primary ATC display used to support the primary tasks of the air traffic controller. The FAA has submitted the final version of the standard for the formal FAA Standards issuing process. As part of the approval process, they have also submitted a project summary and close-out report, including the methods used, bibliography of sources and references, significant issues identified and their resolution, unresolved issues, and lessons learned. (Air Traffic Control/Technical Operations Human Factors)



Information Conveyed by ATC Display

Recent Developments in Turbine Engine Component Risk Assessment Software:

Probabilistic damage tolerance analysis (PDTA) is becoming an industry practice for risk assessment of high-energy rotating components in aircraft gas turbine engines. This approach can address both inherent and induced anomalies associated with the manufacturing process that can lead to rare but potentially catastrophic failures. Summaries of the PDTA process appear in several recent FAA ACs to address specific types of inherent and induced anomalies (AC 33.14-1 and AC 33.70-2, respectively) and to establish a general framework for all life-limited engine parts (AC 33.70-1). Researchers can predict the associated risk of fracture using DARWIN[®], a probabilistic fracture-mechanics software code developed by the Southwest Research Institute under FAA R&D funding.

One of the critical steps in this process is to model accurately the stresses and temperatures applied to crack growth life and fracture risk assessments. For rotating turbine engine components, researchers commonly use axisymmetric finite element models to predict these values. In previous versions of DARWIN[®], fracture analysis was limited to hoop, axial, and radial planes for two-dimensional (2D) axisymmetric models, and visualization was limited to hoop planes. The most recent release (DARWIN[®] 8.0) includes a new capability to define fracture models in general non-hoop stress planes (including maximum principal stress planes) for 2D axisymmetric finite element models. This ensures that researchers perform the analysis for the life-limiting orientation. For non-hoop stress planes, the fracture plane appears as a single line that is coincident with the fracture-plate stress gradient, as shown in Figure 20. The DARWIN[®] auto-modeling algorithms (autoplate, life contours, autozoning) were enhanced to support non-hoop stress planes, in which the maximum principal stress plane is used as the

default stress plane for crack growth life and fracture risk computations. This feature is available for selected univariant crack types (i.e., embedded, surface, and corner cracks).

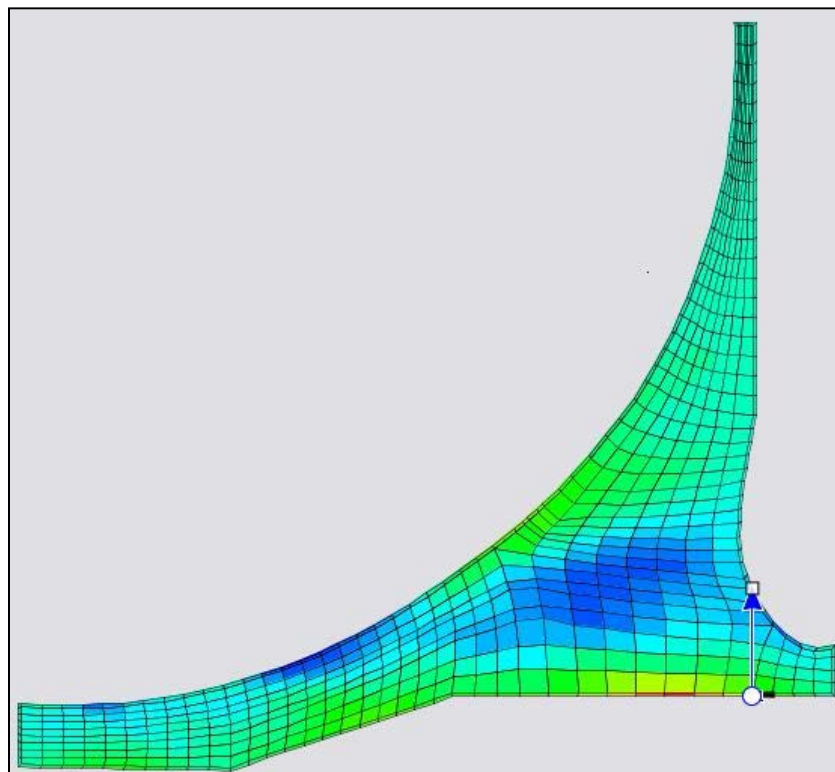


Figure 20: DARWIN® Finite Element Analysis of a Fracture Plate in a Non-hoop Stress Plane

Another critical step in the PDTA process is to model stress-intensity factors accurately for the unique geometries and stress fields associated with rotating engine components, such as 3D hole features with bivariant stresses. DARWIN® 8.0 includes a new bivariant stress-intensity factor solution for semi-elliptical surface cracks at off-center holes (SC29), as shown in Figure 21. Researchers can use the SC29 solution at locations where the stresses change significantly in more than one direction. For univariant stress fields, researchers can use the existing DARWIN® solution for a surface crack at an off-center hole (SC18). SC29 was designed specifically for treatment of hole features described in AC 33.70-2.

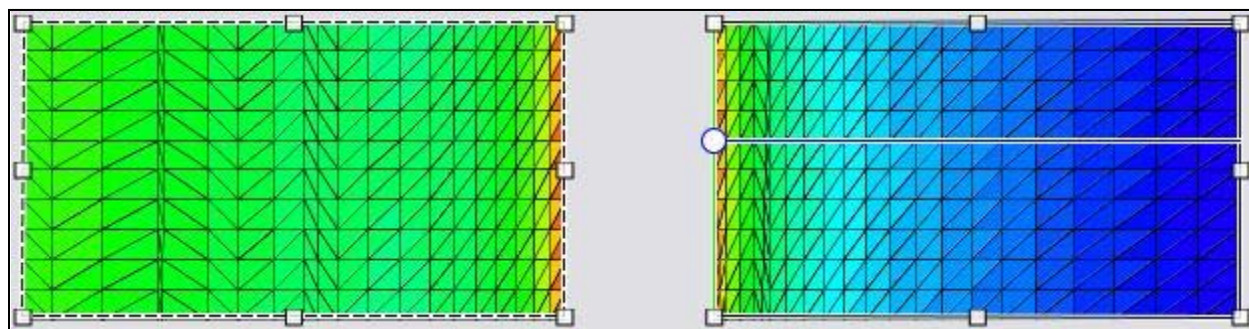


Figure 21: DARWIN® Finite Element Analysis of the New Bivariant Stress-intensity Factor Solution (SC29)

DARWIN[®] 8.0 also includes a new capability to provide treatment for overload crack-growth retardation effects. The new feature enables the analyst to include crack retardation effects for both cycle and time dependent crack growth life and risk assessments. This is especially important for addressing hold time effects at elevated temperatures. (Propulsion and Fuel Systems)

Development of Methods and Metrics to Measure Progress in Reducing the Rate of Fatalities and Significant Injuries by Two-Thirds:

The FAA has completed research to accomplish the goal of demonstrating a two-thirds reduction in the rate of aerospace-related fatalities and significant injuries by the year 2025. Commercial aviation of both scheduled and nonscheduled flights of U.S. passenger and cargo air carriers operated under the Title 14 Code of Federal Regulations (CFR) Part 121 was focused, and the initial result demonstrates that it is possible to achieve the two-thirds reduction goal.

Research analyzed over 900 accidents associated with 14 CFR Part 121 operations occurring in the U.S. between January 1, 1995, and December 31, 2009, and categorized those accidents as groups identified by the Commercial Aviation Safety Team/International Civil Aviation Organization Common Taxonomy Team. Research developed a set of safety metrics consisting of 28 precursors that indicate a strong correlation with fatalities and serious injuries, or both, and can be used to measure, monitor, and predict potential fatalities and serious injuries. Each of those precursors had a sufficiently large number of occurrences available for trend analysis, and could be linked to certain accident categories.

The FAA quantified the precursors to establish the quantitative relation between the precursors and the fatalities and serious injuries so potential fatalities and serious injuries can be predicted by measuring the occurrence of precursors. Researchers quantified two items for each precursor:

- The number of occurrences of a precursor
- The number of fatalities and serious injuries caused by accidents associated with a precursor

The FAA used the NTSB Aviation Accident Database, the FAA Accident and Incident Data System, Service Difficulty Reports, Near Midair Collision System, and an international database for the quantification.

Researchers propose a three-step method to predict the rate of fatalities and serious injuries towards the year 2025 by using the ratio of accident to occurrence, ratio of fatality to accident, and ratio of serious injury to accident. The initial result indicates that the fatality rate and serious injury rate by year 2025 will decline by 76.8 percent and 80.2 percent from their baselines respectively. The result demonstrates that there is a good possibility that the FAA can achieve the two-thirds reduction goal of fatality and serious injury rates by the year 2025. Current research does not consider the impact of NextGen implementation and other safety improvement

efforts. With these ongoing efforts, the results of the reduction of fatality and serious injury rates would be more promising.

The FAA suggests further validation of the metrics and method developed as well as the results predicted in this research when additional safety data from recent years become available.
(System Safety Management)

Evaluation of Flight Management System Performance using Required Navigation Performance Departure Prototype:

A radius-to-fix (RF) turn is a constant-radius maneuver around a point that allows an aircraft to avoid terrain, or conflicting airspace, while maintaining RNP. Whether or not an aircraft is permitted to fly RF turns depends on constraints, its flight management system's algorithms, and the accuracy of flight simulation predictions. A crucial constraint is the maximum bank angle allowed by the aircraft when flying the RF turn, especially on departures. High-fidelity flight simulators that pilots use for training are now used to investigate these constraints and accuracies, but configuring them to replicate in-flight conditions has revealed pitfalls and requires some painstaking preparation. In FY 2012, high-fidelity simulation results, combined with analysis, bench tests, and operational experience were used to support a recommended increase in the bank angle constraint for these turns from 20 degrees to 25 degrees. The significance of this relaxation of the bank angle constraint is that it allows aircraft more leeway to satisfy the RNP, which leads to increased confidence that aircraft will indeed be separated on departures. Figure 22 shows various parameters from the simulator for two different aircraft performing a complicated RF turn. The Ground Trace plot shows data from two combined S-turns. The Ground Speed plot shows ground speed changes as the airplane accelerates along the turn. The Bank Angle plot shows the bank angles of the two aircraft when using the proposed 25 degree bank angle constraint. Finally, the X-trk Error plot shows that both aircraft have less than 0.1 nautical miles of cross track error during the turn, which supports the change in the bank angle constraint. (System Safety Management)

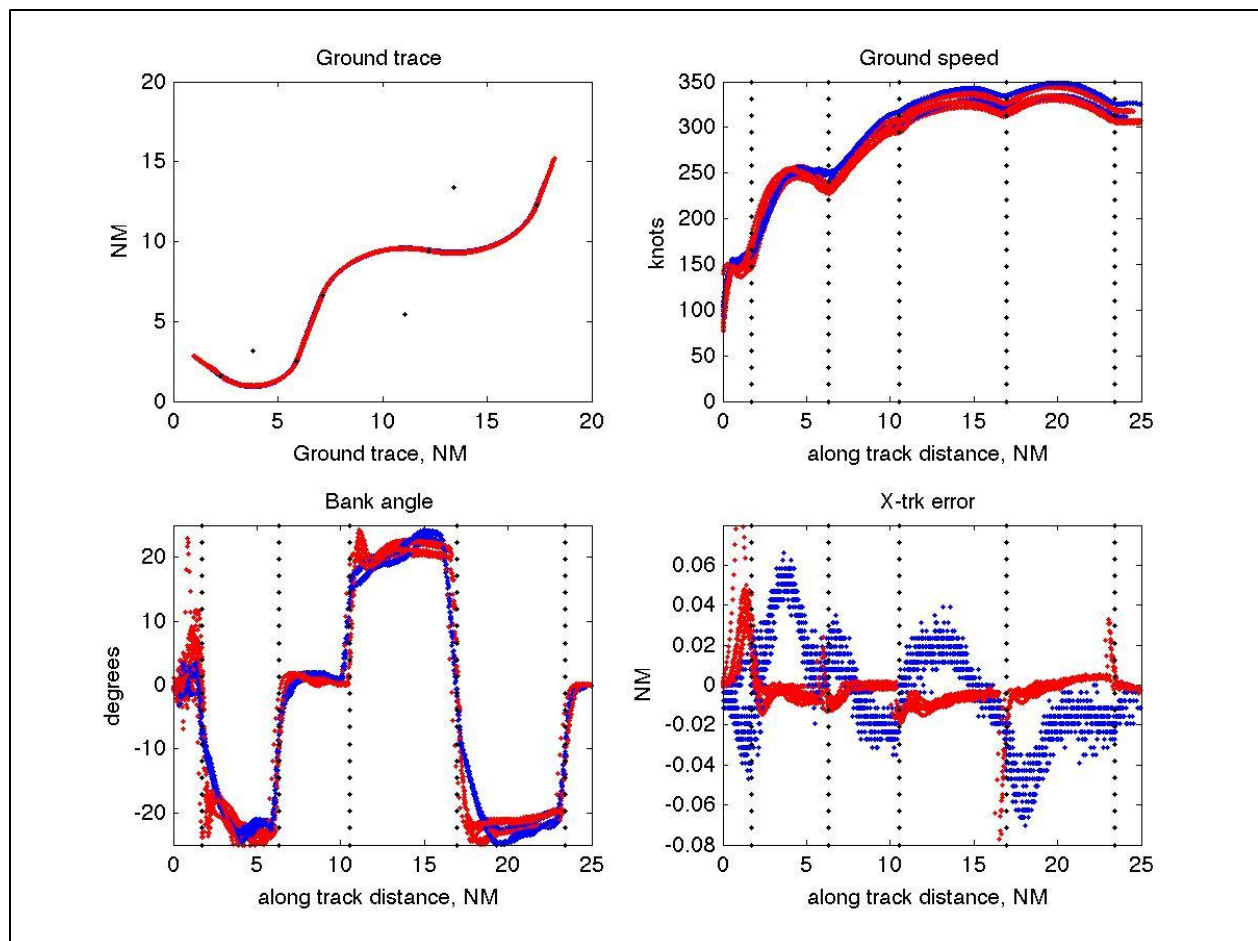


Figure 22: Comparison Results from Two Airplane Simulator Models

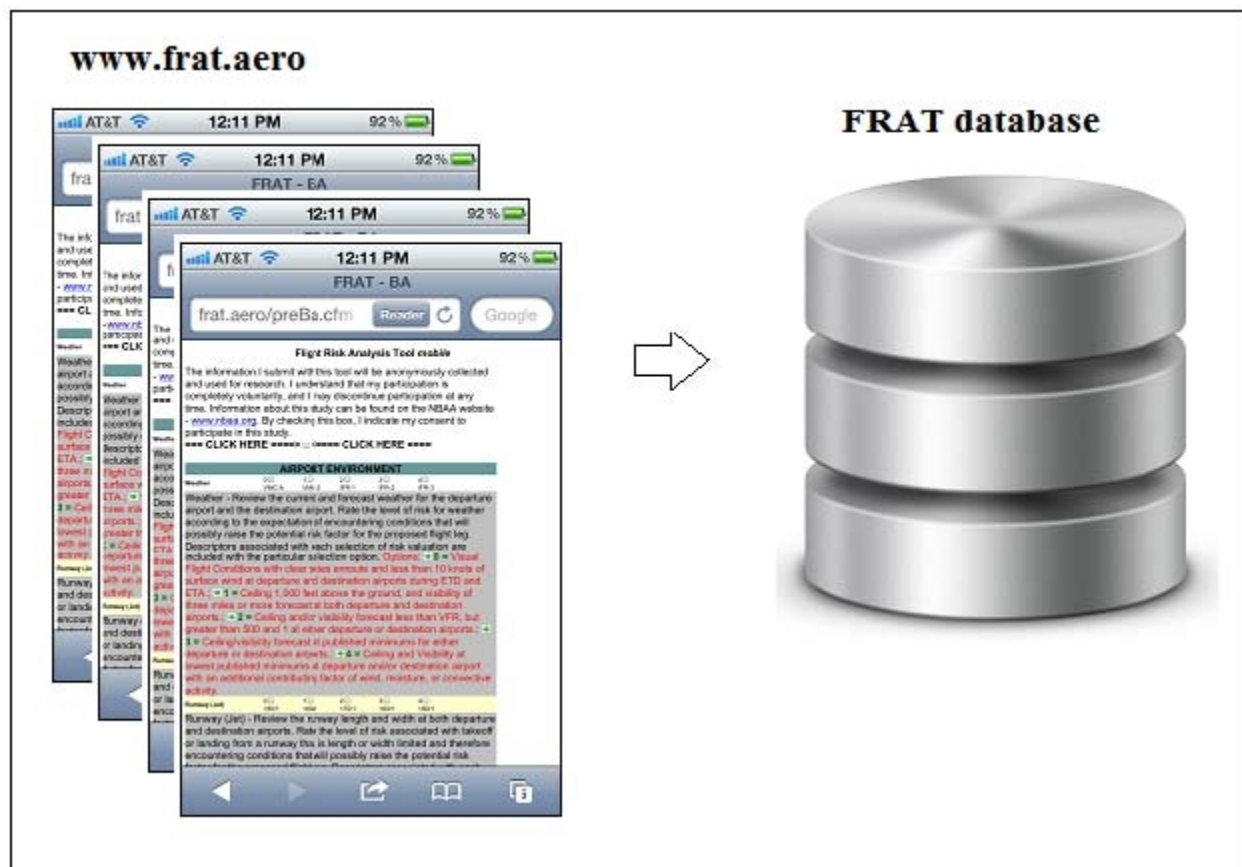
Flight Risk Analysis Tool:

Flight operations use standard operating policies and procedures, such as checklists, forms, and charts, to accomplish tasks in a predictable fashion. These standard operating procedures are designed to identify hazards and mitigate risk. A Flight Risk Analysis Tool (FRAT) allows a pilot or crew to use a checklist-like tool to consider hazards and score risk. Based upon this score, operational decision can be made to reduce the risk.

The FAA, through the Center for General Aviation Research, began in 2011 conducting research to develop a prototype Web-based FRAT for GA pilots. The FRAT is divided into four factor categories (Airport Environment, Crew Experience, Aircraft, and Operating Environment) with a total of 19 individual factors. Based on a pilot's inputs, the scoring matrix of the FRAT computes and advises the pilot of the risk rating as low risk, medium risk, or high risk. Thus, FRAT can be used as an excellent pre-flight review document that can completely analyzes each flight leg during the planning phase and highlights potential hazards. These pre-flight identified hazards alert the pilot and scheduler to the possibility of impending risk.

In addition to helping mitigate risk, anonymous data entered into FRAT represents a potential source of data to aid researchers in advancing the safety of GA. With users' consent, FRAT database collects anonymous data and could share with other safety programs such as the Aviation Safety Information Analysis and Sharing (ASIAS).

As of 2012, FRAT is freely available for all users at <http://frat.aero/> via Web browsers and mobile devices. The FRAT can also be accessed through the National Business Aircraft Association Website under the Aircraft Operations / Safety section. FRAT currently has two modules, one tailored specifically for use by professionally flown flight crews, and another for use by high-performance aircraft owners/operators. The third FRAT module for generic GA segment is being developed. (System Safety Management)

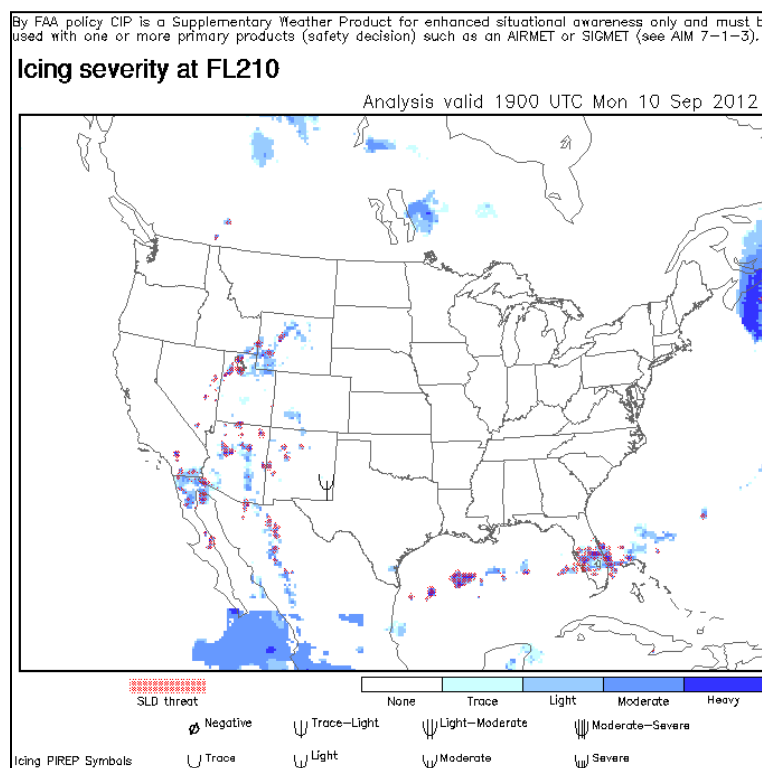


Flight Risk Analysis Tool Screenshots

Avoiding Severe Icing Conditions:

According to NTSB data, in-flight icing causes more than 25 accidents each year, with more than half of those accidents resulting in fatalities and destroyed aircraft. Annually, this equates to more than \$100 million in injuries, fatalities, and aircraft damage. To address this problem, the FAA developed the Current and Forecast Icing Products (CIP and FIP), which provide more accurate and timely diagnoses and forecasts of atmospheric conditions that might lead to ice accretion on aircraft during flight. CIP and FIP run operationally on the Web-based Aviation

Digital Data Service (ADDS) at the National Oceanic and Atmospheric Administration (NOAA) Aviation Weather Center in Kansas City. In FY 2012, the FAA modified the existing CIP and FIP algorithms to use outputs from a new numerical weather prediction model, the Weather Research and Forecast Rapid Refresh (RAP), developed and implemented by the NOAA National Center for Environmental Prediction. RAP is a more efficient weather prediction model than its predecessor, the Rapid Update Cycle, and enhances the accuracy and reliability of both the CIP and FIP products. CIP-RAP and FIP-RAP went operational on ADDS in March 2012. The CIP and FIP automated algorithms gather real-time information from satellites, radars, weather models, surface stations, and pilot reports, and determine the probability of encountering icing, its expected severity, and the likelihood of large droplet icing conditions. This capability is especially beneficial to commuter and smaller aircraft without ice protection as well as those flying at relatively low altitudes (i.e., lower than 24,000 feet) where they are more likely to encounter atmospheric conditions conducive to icing. (Weather Program)

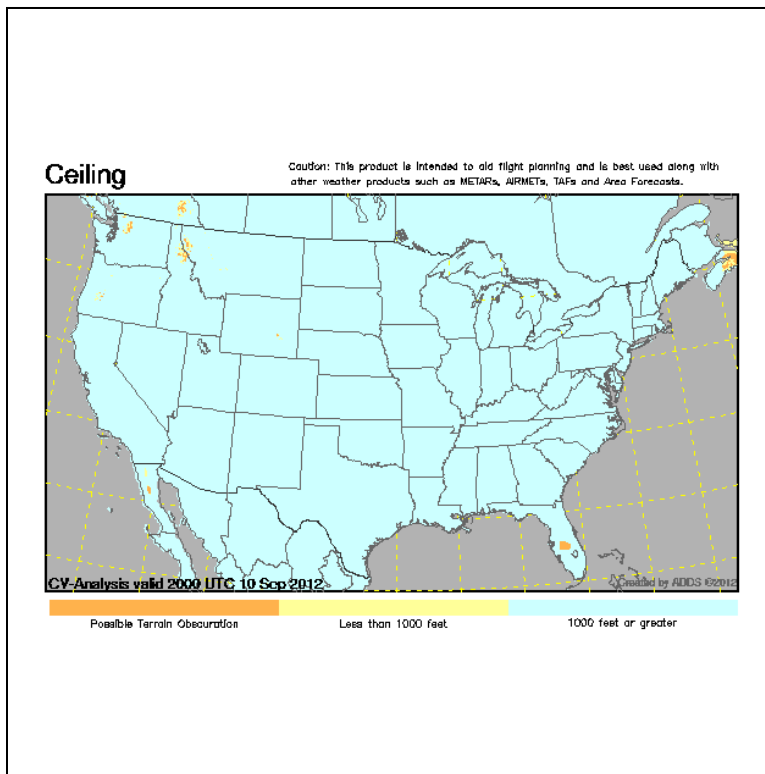


Forecast Icing Product Showing Icing Severity

Enhancing General Aviation Safety:

Each year, low ceilings and restricted visibility are the cause of 72 percent of GA accidents in the contiguous U.S. In Alaska, these cause 55 percent of GA weather-related accidents. Controlled flight into terrain, the most deadly GA weather accident, results either from inadvertent flight into Instrument Meteorological Conditions by a Visual Flight Rules pilot or a poorly prepared IFR pilot. The FAA developed a National Ceiling and Visibility Analysis (CVA) capability that provides real-time analysis of current ceiling and visibility conditions, updated every five minutes with a five kilometer grid, across the continental U.S. In FY 2012, the FAA

implemented this capability operationally onto the Web-based ADDS at the NOAA Aviation Weather Center in Kansas City. As a safety tool to improve situational awareness, CVA targets the safety-of-operations needs of GA. Further enhancement by FY 2016 will include analysis capability for Alaska. (Weather Program)



Forecast Ceiling Product

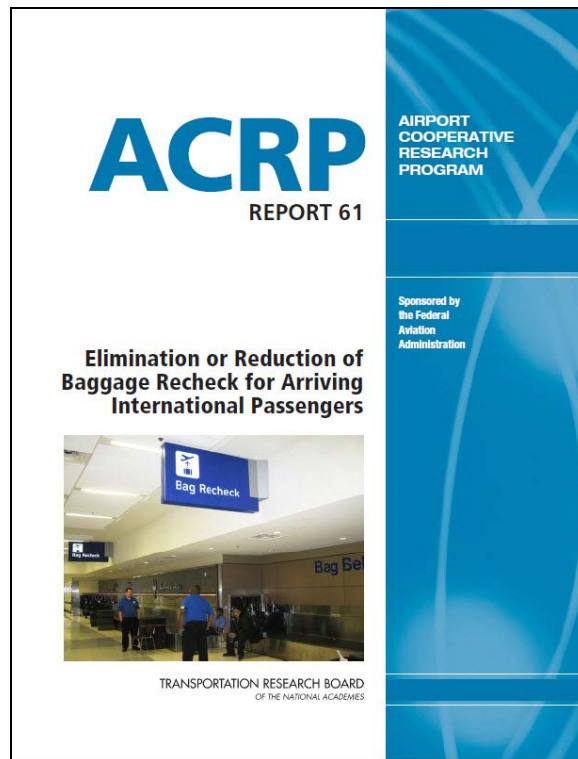
R&D Principle 2 - Improve Efficiency

Systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will improve access to and increase capacity and efficiency of the nation's aviation system.

Elimination or Reduction of Baggage Recheck for Arriving International Passengers:

International passengers arriving in the U.S. and connecting to another destination collect their baggage after they clear U.S. Immigration and before clearance by U.S. Customs and Agriculture (excluding pre-cleared passengers). Non-cleared passengers reclaim their baggage before carrying it through to an area for inspection. At the same time, Federal officials potentially monitor or question passengers with respect to various issues relating to their trip purpose and duration. During this process, the airline handles the passenger baggage several times. In reality, only a very small percentage of passengers receive secondary processing. If staff could quickly identify and retrieve the baggage for these passengers at the request of Federal officials, this would permit other passengers to continue their journey unimpeded through the terminal without having to wait for and recheck their baggage. If this streamlining were possible, there could be a potential for improving operations with cost savings.

The result of this research was the publication of the handbook *Elimination or Reduction of Baggage Recheck for Arriving International Passengers*. This research (1) identified potential alternative procedures that could be implemented to reduce or eliminate the need for the recheck of baggage for arriving international passengers at U.S. airports; (2) described in detail the benefits and costs associated with these alternative procedures to airports, airlines, and Federal agencies; and (3) compared and contrast potential alternative procedures with current practices. (Airport Cooperative Research Program – Capacity)



Measuring Performance of Automated People Mover Systems at Airports:

An automated people mover (APM) is a transportation system with fully automated operations, featuring vehicles on guideways with exclusive right of way. About 30 APM systems are operating at airports worldwide; roughly one-half of these systems are at U.S. airports. APM systems at airports facilitate passenger and employee movement, generally within the confines of the airport. They typically operate from passenger check-in areas to airplane gates and between gates, allowing more people to move more quickly over longer distances, connecting large, often dispersed airline terminals. More recently, airports have designed APM systems to connect airport terminals with parking facilities, car rental services, regional transportation services, hotels, and other related employment and activity centers.

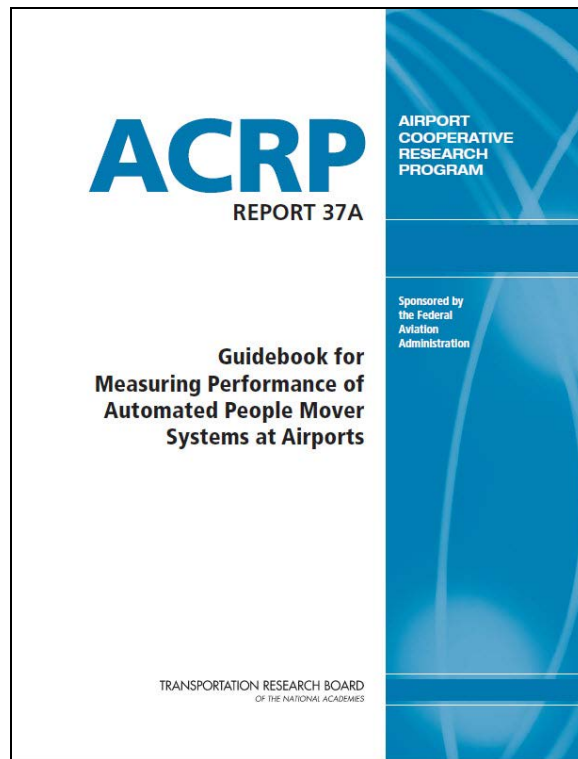
APMs are vital to the operation of many airports, in that they provide the fastest and sometimes the only means to travel within an airport. Serious problems arise for APM passengers and for an entire airport when an airport APM system does not operate well or stops entirely. Operators of APMs at airports routinely collect data and develop performance measures to monitor and manage their performance. These measures typically address service availability, service reliability, cost, and operation and maintenance contract compliance.

Operators of APM systems at airports would like to compare the performance of their systems with that of APMs at other airports to assess and improve their performance. It is a challenge to conduct meaningful comparisons as no two airport-APM systems are identical. The systems have different sizes, configurations, technologies, maintenance provisions, ages, and operating environments. In addition, the FAA must base performance comparisons on comparable

performance measures using comparable data. Currently, no performance measures or data-collection practices common to all airport APMs exist. Research is necessary to develop meaningful tools for measuring and comparing performance.

This research developed the user-friendly *Guidebook for Measuring Performance of Automated People Mover Systems at Airports*. The research approach was to look at APMs from all perspectives – past, present, and future, as well as inward and outward. Specifically, the approach was to look at the historical role of APMs at airports, at present airport applications, and at future technological advances that will allow APMs to meet the needs of tomorrow's airports. At the same time, this guidebook looks inward at the physical components of APMs and outward at the facilities and equipment with which APMs must interface at the airport. To implement this research approach, specific areas or issues were broken out and presented in a sequenced manner that attempts to parallel the progression from planning and design to implementation and operation of actual APM systems. The specific issues of research included: history of APM systems and their roles at airports; APM system characteristics; airport APM planning process overview; needs identification and assessment; matching needs with passenger conveyance technologies; APM system definition and planning methodology; project coordination, justification, and feasibility; APM system procurement; operations and maintenance; and system expansion and overhaul.

The guidebook identifies a set of performance measures and associated data requirements for APM operators at airports to assess and improve performance, compare APM systems, and plan and design future APM systems. The performance measures address the efficiency, effectiveness, and quality of APM systems at airports, particularly focusing on impacts on APM passengers as well as on airport performance. (Airport Cooperative Research Program – Capacity)



Airport Passenger Conveyance Systems Planning:

With air traffic and passenger demand continuing to grow, capacity will continue to be an issue at existing, expanding, and new airport facilities. In addition, the cost of new construction continues to increase, placing a premium on optimization of existing space and planning of new facilities. Peak-period demand accommodating both origin and destination flights as well as connections, both domestic and international, creates complex terminal-design requirements affecting passenger circulation through all areas of an airport.

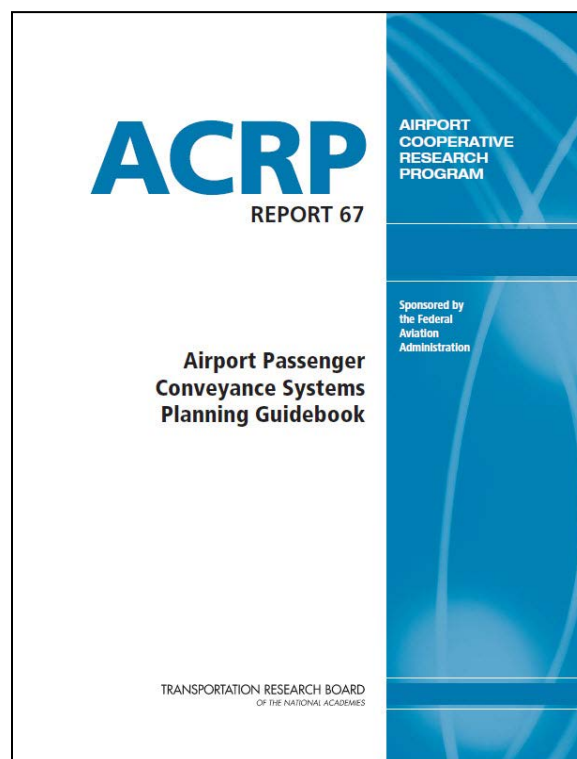
Airport authorities must consider passenger walk distance and ease of use when planning passenger terminal facilities, especially in light of the aging population. In all facilities, vertical conveyance systems, such as elevators and escalators, ease passenger vertical transitions, while moving walkways, passenger assist vehicles, and wheelchairs often reduce walking distance and speed transit through an airport. Interaction of these various components as part of the overall conveyance system within and through the terminal is complex. In addition, how efficiently the system works as a function of terminal design influences passenger flow through the facility, which, in turn, affects overall customer satisfaction.

Even though passenger conveyance systems are available, some passengers will still choose to walk beside the moving walkway, walk while on the moving walkway, or take stairs instead of elevators or escalators. To estimate space requirements for passenger conveyance systems, airport planners and designers must consider passenger choice of walking versus riding. Queue length to access the conveyance system (balking will occur if the queue is too long), congestion on the system limiting the ability to pass, and the perceived length and difficulty of the walk

affect personal choice. Other issues to consider include new and emerging technologies of high-speed and accelerating moving walkways and the ability of older passengers to navigate them.

Conveyance systems all have design capacities, yet these characteristics are often overstated when compared to actual throughput that can be practically achieved in an airport environment. The amount of luggage accompanying passengers and the amount of personal space desired by passengers affect practical throughput. In planning for efficient passenger flow and passenger space requirements, researchers have few studies to understand realistic throughput capacity of passenger conveyance systems. Researchers have collected some data at specific airports as part of modeling studies, yet comprehensive guidelines applicable across airports based on a range of passenger and conveyance characteristics do not currently exist.

This research resulted in the comprehensive *Airport Passenger Conveyance Systems Planning Guidebook* that serves as a decision-support tool for planning, designing, and evaluating passenger conveyance systems at airports. The scope of this research examined how passenger conveyance systems operate and provide service to different areas within the airport environment. For the purpose of this research project, passenger conveyance components included, but were not limited to, escalators, elevators, moving walkways, wheelchairs, and passenger assist vehicles/carts. Research did not include APM systems (covered under other ACRP research projects), Personal Rapid Transit systems, and shuttle bus systems. However, it did include passenger-conveyance system interface with components of the overall airport circulation system. Researchers defined passengers as any individual using the conveyance system. (Airport Cooperative Research Program – Capacity)

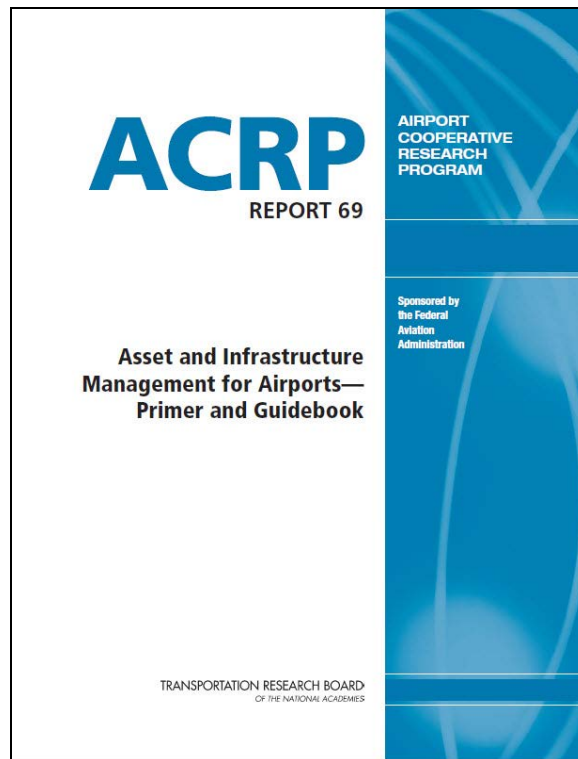


Asset and Infrastructure Management for Airports:

Organizations around the world commonly use asset and infrastructure management to coordinate and oversee the safe, secure, and environmentally sound operation and maintenance of assets in a cost-effective manner. With the limited resources that airports typically face, airport managers constantly seek more efficient and effective ways to manage infrastructure over time. An asset and infrastructure management program can be one such tool. This type of systematic management approach promotes the efficient use of those resources in a proactive, rather than reactive, decision-making process, providing data and information in an integrated manner for the long-term preservation of the asset value.

It is likely that airports already have a systematic data and information process in use to some degree on some of their assets or types of assets. Examples can include pavement maintenance management programs or other computerized maintenance management systems. These data may not be available at the enterprise level, or they may not be formally managed. Many organizations, including airports, operate in a “silo” fashion where it is common that employees have developed their own data and information for the systems in which they are responsible without necessarily sharing access to those systems with other members of the organization. Encouraging centralization of, and access to, these data can enhance the ability of the airport to make effective financial and strategic decisions. Research in this area was done to provide airports with a holistic approach to asset and infrastructure management that includes physical, financial, and human resource assets.

This research resulted in two products. The first is a primer for executive-level decision makers at airports of all sizes that will provide an overview of an asset and infrastructure management program that discusses its components as well as benefits and costs based on experience with existing programs. The second product is a guidebook that provides instruction in the development and implementation of an asset and infrastructure management program that (a) captures best management practices and (b) provides guidance in developing and incorporating asset and infrastructure management programs at airports of all sizes. (Airport Cooperative Research Program – Capacity)



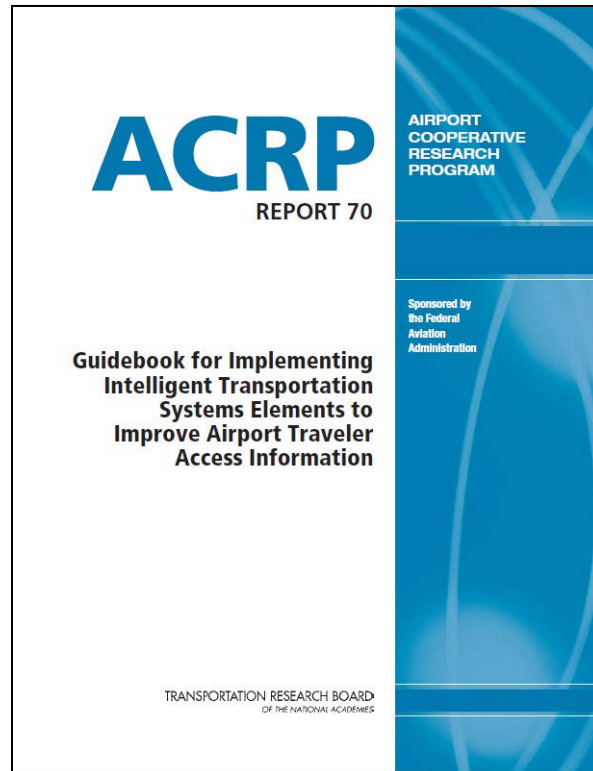
Applying Intelligent Transportation Systems to Improve Airport Traveler Access Information:

Many airports have developed elaborate and often highly sophisticated programs for providing travelers with ground access information, but no common format exists for presenting this information to the public, either on airport websites or via other electronic media. As U.S. airports consider making new or expanding existing capital investments to improve public access, there is increasing interest in the potential for creating a consistent format for presenting information quickly and effectively on viable ground-access travel options using Intelligent Transportation Systems (ITS) technology. In the broadest sense, ITSs encompass a range of wireless and wired communications-based information and electronics technologies. Although many metropolitan areas are developing traveler information systems, few existing systems address ground access requirements specific to airport travelers.

Airport travelers have become accustomed to acquiring necessary information using technology. In addition, travelers to and from airports, both resident and non-resident, often need real-time information about parking availability, access delays, and alternative travel modes. Research is necessary to provide uniform guidance to assist airports in providing pre-trip planning and real-time information in a consistent or similar format.

This research (1) described opportunities for using ITS technology to help travelers simply, efficiently, and interactively evaluate their airport ground transportation options; and (2) prepared a guidebook for use by airport operators (in cooperation with transportation service providers) to develop and implement ITS solutions specific to their environment. The guidebook encompasses existing and emerging technologies for presenting useful information, addressing

all forms of ground transportation available to travelers to and from the airport. The guidebook (1) identifies options for providing interactive pre-trip planning using real-time information on ground access services and facilities and (2) provides functional specifications for and a mock-up of a Web-based or other technology-based information delivery system for trip planning, adaptable for use at a wide variety of airports with a reasonable degree of commonality. The guidebook includes a CD containing a downloadable version of the mockups and an interactive demonstration using a suitable application platform. The ITS approach considers how desired traveler information can be provided using a framework similar in content yet customizable by individual airports. (Airport Cooperative Research Program – Capacity)



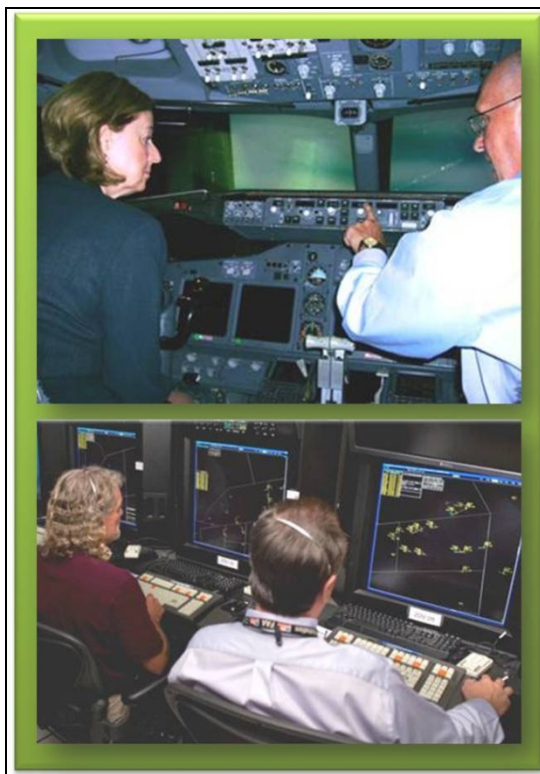
FAA PAVEAIR Web-Based Airport Management Software Update:

The FAA requires AIP grant recipients to “develop and maintain an effective airport pavement maintenance management program.” To facilitate airport pavement management best practices and to assist airports in fulfilling the requirements of AC 150/5380-7a, the FAA Airport Technology R&D Branch developed and maintains FAA PAVEAIR, a free, web-based airport pavement management software application. A new version of FAA PAVEAIR, v2.0, was released on September 6, 2012. FAA PAVEAIR v2.0 is freely available to the public at www.pavaeair.faa.gov. One of the major improvements in the current version of FAA PAVEAIR is an updated and redesigned Maintenance and Repair (M&R) module. The M&R module is used to assist in the scheduling, budgeting, and analysis of pavement maintenance and repair activities. Other significant upgrades in FAA PAVEAIR v2.0 are the addition of a new Life Cycle Cost Analysis module and support for the MicroPAVER™ e65 data format. Also,

data entry has been made more user friendly, with support for rapid data entry using the keyboard and intensive error checking and validation features. An FAA PAVEAIR user group was formed and met most recently in September 2012 in Salt Lake City, Utah. Further enhancements to the FAA PAVEAIR application are planned based on feedback from this group. (Airport Technology Research Program – Capacity)

Three-Dimensional Path Arrival Management Project:

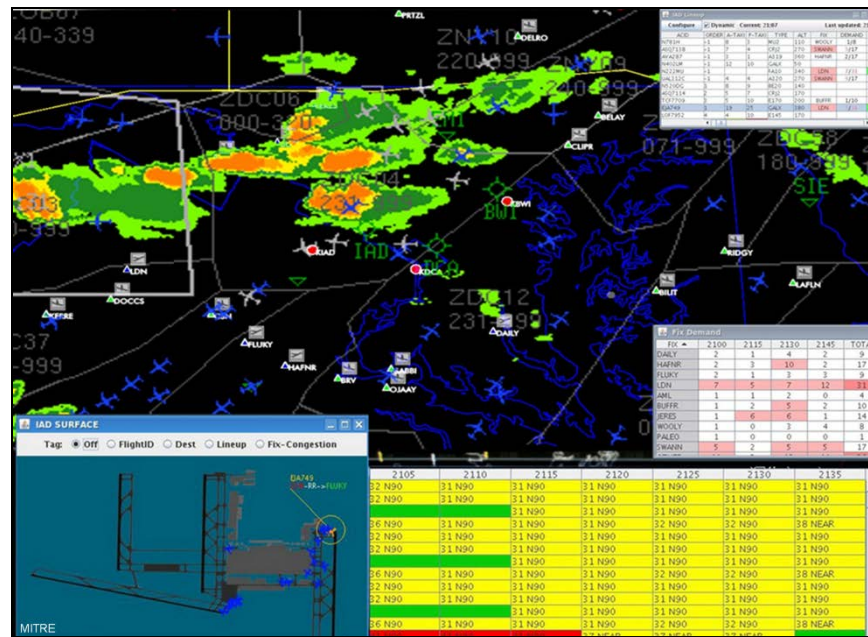
The Three-Dimensional Path Arrival Management (3D PAM) Project was successfully transferred to the Traffic Flow-based Management Office in November 2011. The 3D PAM concept is a capability enabling trajectory-based operations in high-density arrival airspace using voice communications. This capability takes advantage of flight-deck automation currently available in most modern airline transport, regional and business jet aircraft. NASA developed a new ground automation-decision support tool in partnership with the FAA as the core enabler of 3D PAM concept. The tool, known as the Efficient Descent Advisor (EDA), generates four-dimensional (4D) trajectories that controllers will issue via voice and later using data communications (Data Comm) to arriving aircraft. The EDA tool generates a highly accurate, conflict-free, and fuel-efficient trajectory that controllers send to each aircraft. The aircraft's flight computer, known as the Flight Management Computer, flies the trajectories. The trajectory enables a gradual descent at minimum power from cruise altitude to a meter fix located around all large airports for the sequencing and spacing of aircraft. During the development phase of the project, seven ATC centric, human-in-the-loop (HITL) simulations and seven flight-deck centric HITLs were successfully performed. In addition, two flight tests occurred at Denver International Airport involving airline transport aircraft from United Airlines and regional jets from SkyWest Airlines. All the simulations and flight-testing contributed to the development of EDA tool and the overall 3D PAM concept. This project was conducted as a partnership among the FAA, NASA, The Boeing Company, and United Airlines, and SkyWest Airlines. Denver Center controllers participated in all air traffic simulations and in the flight-testing. They were instrumental in the development of EDA and the overall concept. (Operations Concept Validation Modeling)



3D PAM Demonstrations and Analysis

High Density Departure Arrival Management:

In today's operations, a lack of efficient information, such as integrated traffic, weather, and airspace resource information, can result in traffic managers reacting to disruptions as opposed to planning mitigation strategies proactively. The lack of situational awareness regarding departure route availability, operational concerns, or airspace constraints in adjacent facilities impedes inter-facility coordination. Decisions made without sufficient coordination or supporting data can result in unintended disruptions to the NAS and delayed flights.



High Density Area Departure/Arrival Management (HDDAM)
Screen Shot

CAASD has been exploring a concept called High Density Area Departure/Arrival Management (HDDAM), which attempts to align the decision-making authority with the information available to each decision maker and the impact of the decision on his or her operating environment. The HDDAM concept redefines the scope of decision making between the Air Route Traffic Control Centers (ARTCC), Terminal Radar Approach Control Facilities (TRACON), and towers by constructing the roles and responsibilities in a manner that encourages proactive planning. The objective of this research is to create an experimental environment in which the redistribution of the roles and responsibilities among the decision makers in different facilities can be demonstrated and evaluated. In this environment, decision makers receive integrated traffic, weather, and airspace resource information as well as the decision support tools developed to aid decision making under the new framework.

In FY 2012, the FAA conducted a HITL experiment to contrast the differences between today's operational environment and the HDDAM environment. The experiment required participants to develop congestion resolution procedures under three scenarios: a departure-impacting event, an arrival-impacting event at Washington's Dulles International airport, and an event that would potentially affect both departures and arrivals. Several participants using tools and approaches available in today's operations environment and under a simulated HDDAM environment evaluated each scenario.



HDDAM Toolset

In the current day simulation, air traffic managers defined mile-in-trail restrictions, reroutes for individual flights as well as entire flows, route closures, and ground stops. Participants used vastly different approaches to mitigate the congestion defined in the scenario, resulting in a wide variability of impact. In the HDDAM environment, participants set capacities of routes and fixes as well as departure and arrival rates at airports. Researchers managed interaction effects at the TRACON through slot allocation. In general, this produced results that are more consistent across scenarios. Contrasting results from the two approaches included the following: in current-day cases where researchers issued only mile-in-trail restrictions and reroutes, the delays were often much lower than seen in the HDDAM environment; however, in cases where researchers issued ground stops or Approval Requests, the resulting delays were significantly higher. This dichotomy highlights an issue in today's operating environment, namely that inconsistent approaches to traffic-flow event management can yield significantly different outcomes. A key finding of this research was that the HDDAM environment significantly reduced this level of variability. (Center for Advanced Aviation System Development)

Required Time of Arrival (RTA) Flight Trials:

In the fall of 2011, the FAA and CAASD completed successful flight trials as part of the NextGen demonstrations for Trajectory-Based Operations. These trials assessed the operational viability of the use of the Required Time of Arrival (RTA) function in the NAS. The RTA function is available in modern flight management systems to provide improved meter fix delivery accuracy. The airline partner for these trials was Alaska Airlines, and the trials included all of their B-737 revenue flights arriving into Seattle-Tacoma International Airport. Trial flights were issued specific times to arrive over meter fixes when they were approximately 250 nautical miles from the TRACON boundary the tower issued. Traffic Management Advisor, an arrival-flow management tool available to the Seattle ARTCC, computed the times. These trials included three arrival routes and their associated meter fixes (see Figure 23), uplink of forecast winds, and real-time air-ground data exchange of 4D Intent information that was shared with ATC for issuance of RTAs.



Figure 23: Seattle RTA Trials Illustration

The objectives of the flight trials included the following: (1) increased exposure of RTA concepts/procedures to controllers and flight crews; (2) increased acceptance and execution rate of RTA assignments from the previous flight trials; (3) a streamlined process for assignment of RTAs; (4) facilitation of a more in-depth evaluation of the concept; and (5) an assessment of the viability of RTA as a useful tool for controllers and operators.

Over the 23-day trial period, controllers issued RTAs to the meter fix for 833 flights. Figure 24 provides a breakdown of the results of the 833 RTA issuances.

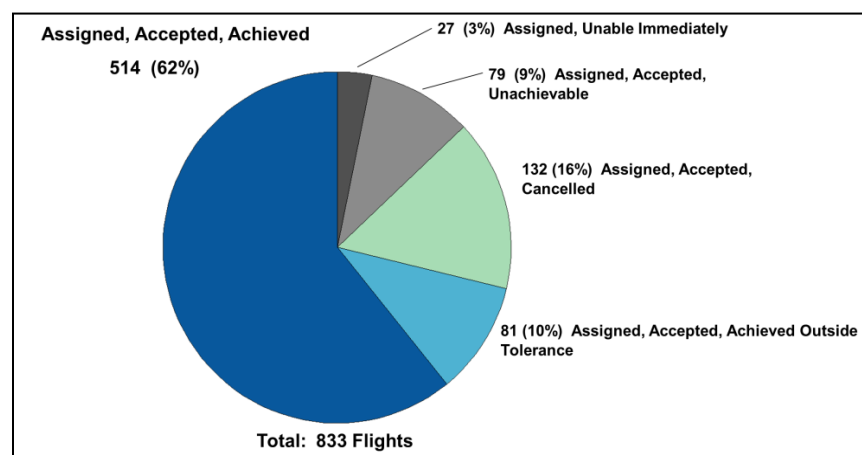


Figure 24: Seattle RTA Flight Trials Outcomes

To provide more opportunities for ATC familiarization of RTA, the Alaska Airlines fleet had been enabled to downlink 4D intent messages through the Aircraft Communication Addressing and Reporting System. These intent messages contained planned 4D (three-dimensional plus time) trajectory information, the RTA value issued, the earliest and latest time to reach the waypoint with RTA, the uplinked wind values, and the aircraft position.

ACID	Meter Fix	ETA Cockpit	RTA Cockpit	RTA Earliest	RTA Latest	Winds Loaded	Perf Limits Loaded	Minutes Since Last Downlink	Comments
AS15	JAKSN	05:01:14				N	N	04	
AS76**	JAWBN	00:40:18 **				N	N	00	
AS509	OLM	23:55:11				Y	Y	09	
AS605	OLM	00:03:06				Y	N	03	
AS327	OLM	00:29:49	00:29:58	00:29:00	00:29:49	Y	Y	03	0030
AS555**	OLM	00:45:46 **	00:42:57	00:40:45	00:47:37	Y	Y	01	0043
AS487	OLM	01:05:52				N	N	00	
AS455	OLM	01:26:58				N	N	04	
AS507	OLM	01:59:15				N	N	03	
AS633	RADDY	00:51:20	00:51:22	00:50:30	00:55:48	Y	Y	05	
AS743	RADDY	03:59:03				N	N	02	
AS19	RADDY	04:52:59				N	N	01	

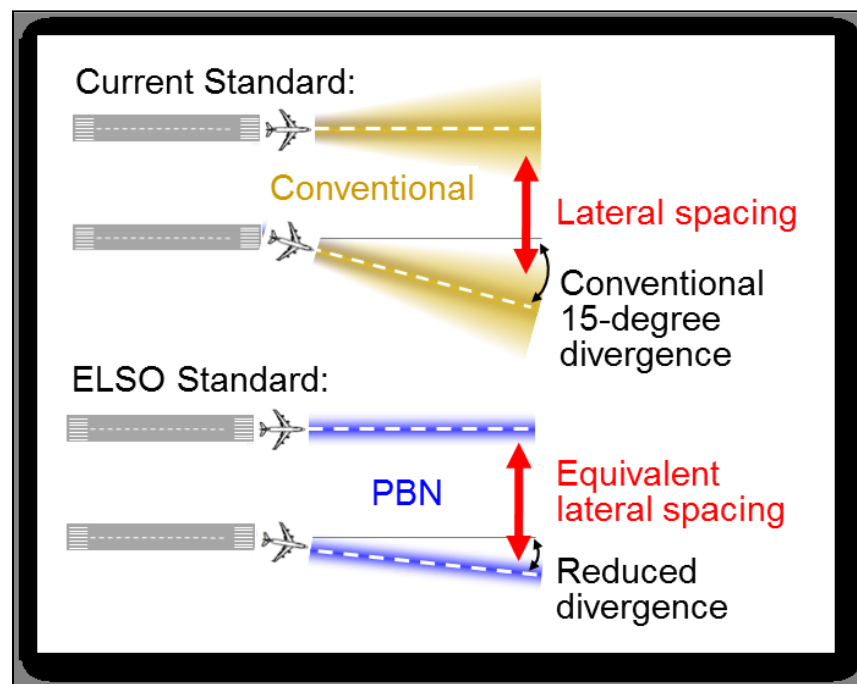
Seattle RTA Flight Intent Display

The RTA information appeared on a real-time display in the Traffic Management Unit to allow the Traffic Management Coordinators to evaluate the utility, quality, and necessity of having this type of information to conduct RTA operations. This display, shown above, enabled the sharing of aircraft intent information with the ground for improved decision making and monitoring of aircraft performance. (Center for Advanced Aviation System Development)

PBN-Based Separation Standards:

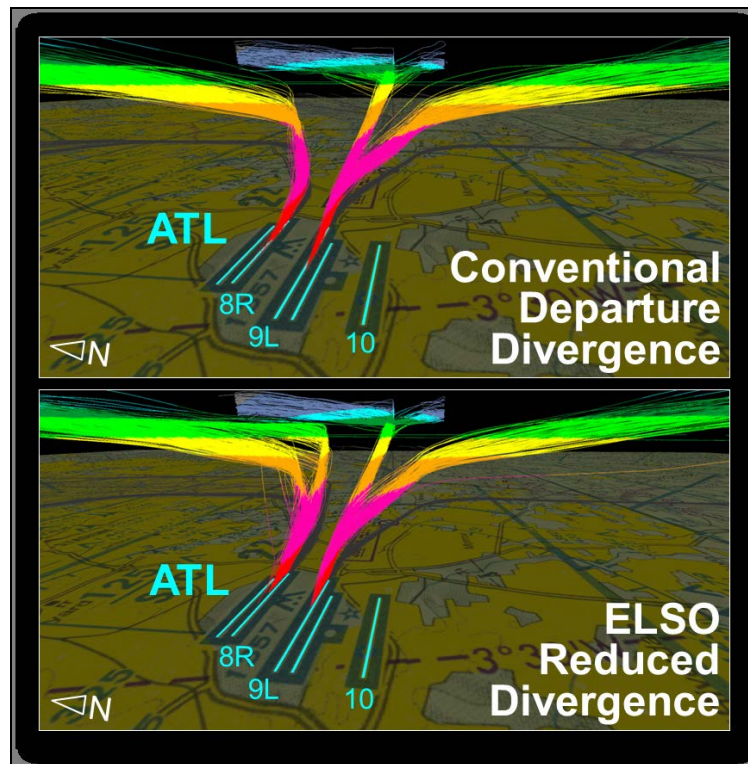
In FY 2010, CAASD proposed capitalizing on the improved navigational precision of PBN operations to evolve applicable separation standards and enable near-term improvements of operational efficiencies in the terminal area. The research resulted in the development of the Equivalent Lateral Spacing Operation (ELSO) standard concept. The ELSO concept takes advantage of advanced RNAV equipment already installed and used in most aircraft. It redefines the minimum angle required between diverging departure routes. Unchanged for the better part of half a century, the conventional separation standard still in use today requires a 15-degree difference, or divergence, between departure routes. Taking into consideration the precision

with which today's aircraft navigate along advanced RNAV routes and specific runway layout geometries, the ELSO concept reduces the divergence angle by about one half of the conventional 15-degree standard if departures take off from parallel runways, and by about one third if the aircraft are cleared to take off on the same runway. This concept is illustrated below. When these airspace-saving reductions enable the use of additional departure routes, aircraft can be cleared for takeoff more efficiently, thus increasing the departure capacity without any infrastructure changes.



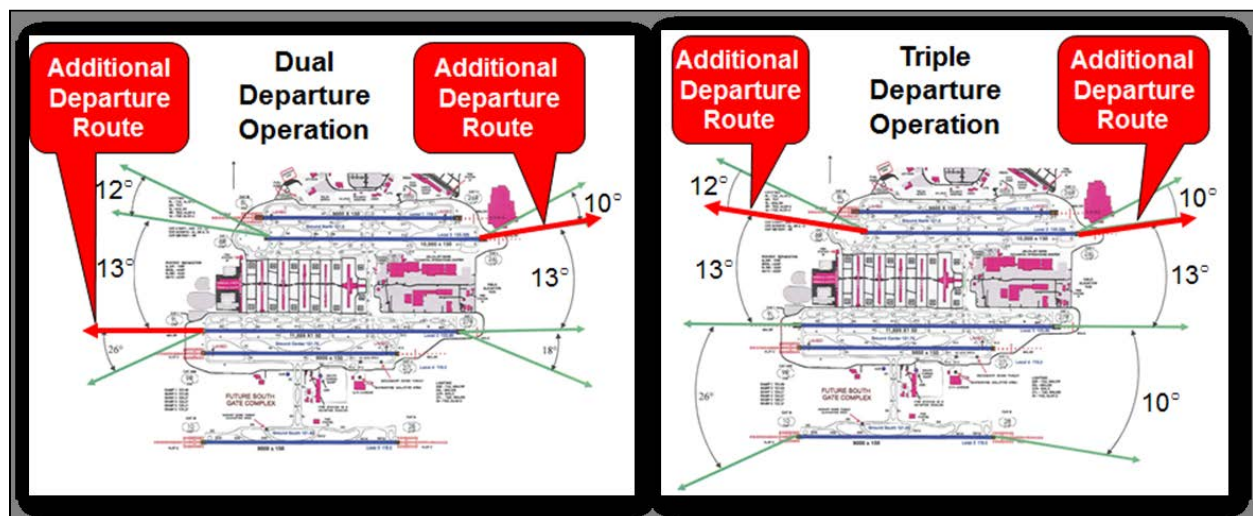
Equivalent Lateral Spacing Operations – Concept

In FY 2011, CAASD applied ELSO-based minimum divergence requirements to revised RNAV Standard Instrument Departure procedures at Hartsfield-Jackson Atlanta International Airport (ATL). At ATL, the new separation standard allowed for the design of a fourth departure route in airspace that previously supported only three routes. Significant RNAV ELSO procedure design elements showing reduced divergence angles for successive departures and dual/triple simultaneous parallel departures are illustrated below for ATL. Upon technical review of the ELSO concept by the FAA Flight Technologies and Procedures Division and the Office of Safety, a waiver to FAA Order 7110.65 was issued on August 22, 2011. The waiver authorizes ATL to conduct reduced-divergence departure operations by implementing RNAV ELSO procedures. On October 20, 2011, ATL implemented the RNAV ELSO procedures, which increased the number of aircraft the airport can clear for takeoff by about 10 additional departures per hour.



Atlanta Departures under Conventional and Reduced-Divergence
RNAV ELSO Procedures

In FY 2012, CAASD evaluated the post-implementation gains in operational efficiencies and quantified resulting benefits. Analyses of surveillance data recorded before and after implementing the RNAV ELSO confirmed that there were improvements in departure efficiency. The illustration below shows radar tracks of ATL departures and illustrates operations along the routes of conventionally diverging procedures and the new reduced-divergence RNAV ELSO procedures. Reductions in departure delays were determined using a model of ATL departure operations.



Atlanta New ELSO Separation Standard – 4th Departure Route

The model was validated to reflect ATL's actual pre- and post-implementation departure performance to ensure that estimated benefits resulted from the operational changes directly associated with the implementation of the RNAV ELSO departure procedures. Researchers estimated benefits to aircraft operators at an average of \$44.00 per ATL departure and an annual airport total of \$19.2 million for the first year. Based on FAA departure demand growth projections for the airport, cumulative operator benefits were estimated at approximately \$1 billion for the 2011–2021 period. These results demonstrate the near-term benefits of ELSO-enabled reduced-divergence departure operations at ATL and pave the way for application of PBN-based separation standards across the NAS. (Center for Advanced Aviation System Development)

Framework for Prioritizing Multi-agency Research Needed to Achieve the NextGen Vision:

In November 2011, the Joint Program Development Office (JPDO) published the *Targeted NextGen Capabilities for 2025* document, which focuses research and system implementation investment decisions by identifying the NextGen elements that the FAA can achieve by 2025. The document presents capabilities and their deployment in the 2025 timeframe, based on the JPDO and its partner agencies' modeling, financial analysis, and studies. It also provides a baseline for further engagement with stakeholders in maturing the collective understanding of the NextGen vision. The document depicts this vision using operational descriptions that trace the phases of a "NextGen 2025" flight using key capabilities that will enhance airspace safety, security, efficiency, and environment compatibility. The document is available at: http://www.jpdo.gov/library/2011_Targeted_NextGen-Capabilities_for_2025_v3.25.pdf. (Joint Program Development Office)



JPDO *Targeted NextGen Capabilities for 2025* Document

NextGen Mode Awareness:

Mode errors occur in the cockpit when pilots do not correctly identify or predict the operational and functional states (modes) of automated systems. Loss of mode awareness can lead pilots to make inappropriate control inputs, which researchers cite as a contributing factor in several high-profile aviation accidents. Due to the volume and complexity of how systems interact in current flight systems, maintaining mode awareness in the face of increased automation is already challenging for pilots. Given the anticipated complexity of integrating new technologies, e.g., satellite surveillance - and the advanced applications these technologies support - into the automated framework of future advanced aviation systems under NextGen, the challenge of mode awareness will become even more pronounced. The University of Central Florida (a) reviewed the state-of-the-art in mode awareness research, (b) identified current known mode and mode transition issues, (c) investigated technologies being developed for NextGen regarding their potential impact on mode awareness, and (d) identified key mode awareness issues for near- and mid- term NextGen applications. The project report provides scientific and technical background information for the development of minimum operational guidelines to reduce mode errors in near- and mid-term NextGen operations. (NextGen – Air Ground Integration Human Factors)

Database of NextGen Human Error Hazards:

As part of the Air Traffic Organization's emphasis on SMSs and safety risk analysis, the contribution of human error in system safety has taken on new importance. In FY 2012, researchers created a database of NextGen Human Error Hazards, which is a repository of prioritized human performance hazards and associated mitigation strategies. The database contains human performance hazards from many human factors safety analyses, including assessments of the OV-6c (Operational Event) scenarios, Data Comm Segment 2, and the NextGen Segment Bravo operational improvements and increments. The database allows a user to filter and review human performance hazard details, such as hazard conditions, human error potentials, mode errors, worst credible outcomes, and human performance risk categories. Researchers identified hazard mitigation strategies of design, training, and research requirements for each human performance hazard. The database is available for use in system safety and risk analysis for new ATC capabilities. (NextGen – Air Ground Integration Human Factors)



Human Performance Hazards

NextGen Data Communications:

One major enabling technology of NextGen is Data Comm, which is an electronic text-based message-transferring system between aircraft and ground stations. Data Comm is critical to ensuring that data are available to flight deck automation and to providing real-time data to ATC. Switching to Data Comm as the primary method for communicating between the flight crew and ATC will require the development of flight deck procedures for interacting with Data Comm. Since Data Comm is a different modality from voice communications, current flight deck-ATC procedures will require modification. Human factors issues for Data Comm procedure development include who should have responsibility for Data Comm in the flight crew, how using Data Comm will affect workload on the flight deck, and how to minimize communication errors. Researchers at George Mason University executed two projects to address related objectives: (1) assess pilot situation awareness, decision-making, and workload with Data Comm compared to voice communications; and (2) evaluate procedures for receiving and reading Data Comm messages and generating the appropriate response. Results from the first project implied that with a well-designed Data Comm interface, sufficient training, and clear procedures, there might not be a loss of situation awareness, degradation of decision-making, or increase in workload when using Data Comm instead of voice communications. The second project, consisting of two sequential research studies, evaluated alternative flight crew procedures. The results from the second project suggest that the optimal procedure would be for both pilots to read the clearance silently, and then for the pilot monitoring to initiate discussion toward obtaining pilot flying concurrence by reading the clearance aloud. The FAA can use the results from both projects to inform further Data Comm procedure development and eventual procedure implementation supporting NextGen operations. (NextGen – Air Ground Integration Human Factors)



Flight Deck Data Comm

NextGen Strategic Job Analysis: Selecting the Air Traffic Controller of the Future:

NextGen will introduce new technologies and procedures to the ATC system by about 2018. At the same time, the FAA is hiring the next generation of air traffic controllers as older controllers, hired largely between 1981 and 1992, retire. What are the aptitudes - the fundamental human abilities and other personal characteristics for which the FAA provides no training - that newly hired controllers will need in view of NextGen? The FAA designed this research to identify any gaps in FAA controller aptitude testing in terms of a comparison of current to future (at about 2018) ability requirements.

There are two key accomplishments from this research. First, the FAA developed a Web-based relational database application to make existing and future job and task analysis information more readily available in electronic (rather than paper) form for analyses, such as this strategic job analysis. This database application enables a central repository of controller job and task analysis information, including descriptions of the performance measures, work, knowledge, skills, abilities, and other personal characteristics to be made available to the human factors and training communities. Second, researchers analyzed the impact of mid-term NextGen operational improvements, technologies, and procedures on the aptitude requirements for the controller occupation in each operational environment. The major finding is that the aptitude profile likely to be required to enter the controller occupation in the mid-term at about 2018 is not dramatically different from the current profile of required aptitudes. The FAA used these results of these analyses to identify gaps in aptitude testing and to make recommendations for additional tests that researchers will incorporate into the test battery incorporated into the test battery. (Air Traffic Control/Technical Operations Human Factors (Controller Efficiency and Air Ground Integration))



FAA Training Program

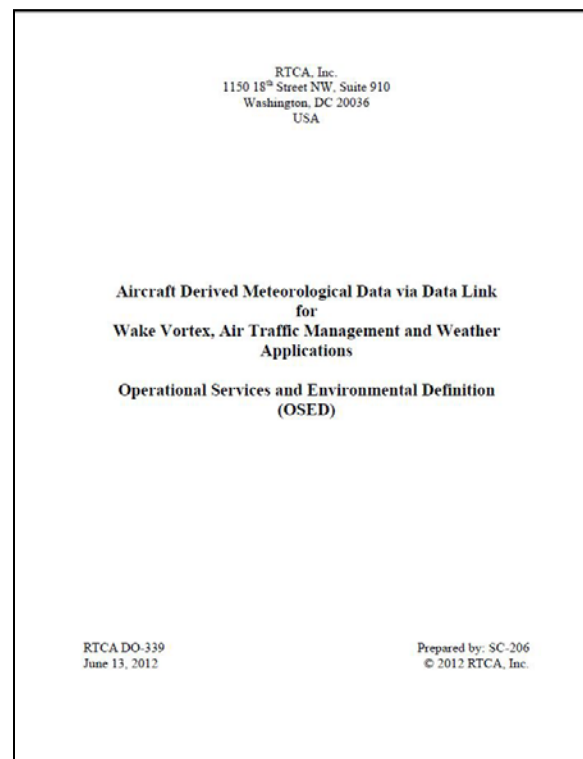
Design Process Guide for Human Factors Ergonomics:

Standards and guidance for the definition of human factors ergonomic requirements for systems are found in large, difficult-to-use documents and rely largely on the expertise of the specific practitioner. Additionally, dependencies among design choice exist, which are not clearly identified, such as the relationship between viewing distance to a display and the required minimum font size to be able to read the text. Leveraging work underway for the German Air Traffic Authority, researchers at the University of Darmstadt produced a functioning, Web-based prototype of the Design Process Guide (DPG). The DPG is a database driven tool to extract specific ergonomic requirements as well as identify and resolve cross-requirement dependencies. The researchers have defined the network of requirements, identified many of the cross-requirement dependencies, and provided a partially populated DPG, which both demonstrates the functionality of the tool and is amenable to expansion. (Air Traffic Control/Technical Operations Human Factors)

RTCA Issued DO-339 – Aircraft Derived Meteorological Data via Data Link for Wake Vortex, Air Traffic Management and Weather Applications – Operational Services and Environmental Definition:

Aircraft flight characteristics (e.g., aircraft weight, aircraft type, trajectory, etc.) and weather observed by the aircraft (e.g., wind and its direction, turbulence of the atmosphere, humidity, temperature, etc.) are vital information elements for many future NextGen-era ATC and management applications needed for the efficient and safe use of constrained airspace and airport runways. Safe reduction of required wake turbulence separations between aircraft is one application that promises significant enhancement to airspace and airport capacity. The FAA and MITRE Corporation's CAASD led the RTCA Special Committee 206 – Subgroup 1 to successfully obtain concurrence among its international government and aviation industry

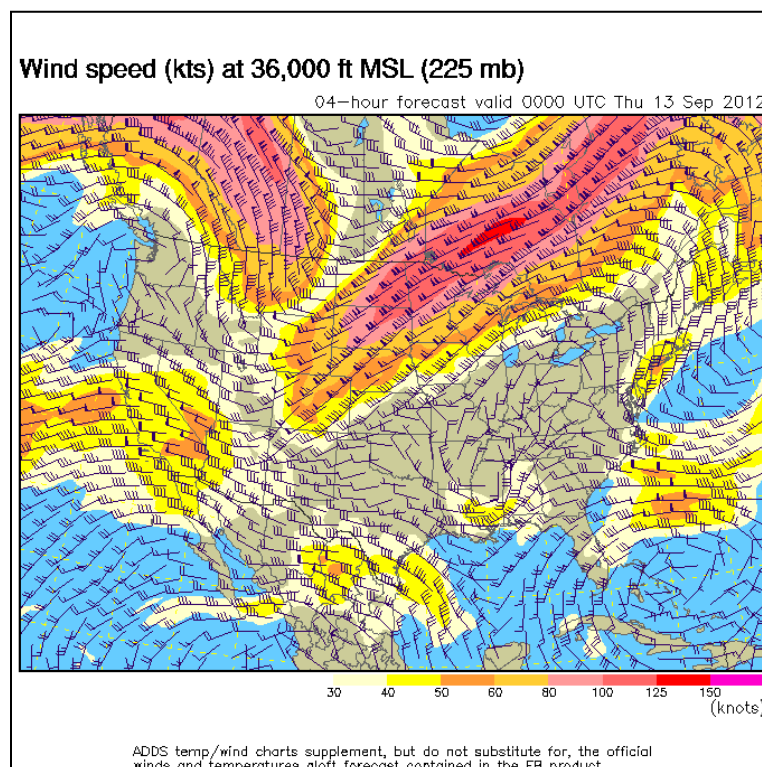
participants on an operational concept and associated set of data elements for the acquisition and use of aircraft-derived meteorological data for immediate tactical applications. The RTCA and Special Committee 206 took the unusual step of publishing this concept document under a green cover (DO-339) as a standalone document because it represents a potential “sea change” in the thinking related to acquisition and use of aircraft-derived meteorological data. DO-339 describes the specific data to be transmitted as well as provisions for participation by aircraft not equipped with data buses and/or flight management systems; discusses constraints under which the proposed service must operate; and provides an overview of potentially applicable performance standards, error handling, system safety, and system security topics. Domestic and international stakeholders and subject matter experts in wake turbulence, interval management, meteorological forecasting, meteorological data distribution, aircraft avionics, and ADS-B data link technologies participated in the Subgroup 1 activity. These stakeholders and subject matter experts contributed operational concepts, system requirements, and initial quantitative analysis to the Subgroup-1 activity based on current and past research activities in their respective fields. Over a three-year development period, Subgroup 1 distilled these inputs into a consensus concept for a data service implemented on existing air-to-ground and air-to-air data links that the entire SC-206 membership and the RTCA Program Management Committee approved. (NextGen – Wake Turbulence)



Enhanced Weather Models Improve Aviation Weather Forecasts:

In-flight icing, turbulence, convective weather, and low ceilings and visibility affect both the safety and capacity of the NAS on a daily basis. Timely and precise forecasts of these aviation-specific weather hazards require forecast models that are not only accurate and updated

frequently, but that can be easily modified as enhancements become available. To that end, the FAA, in collaboration with NOAA, the Air Force Weather Agency, the Naval Research Laboratory, the National Center for Atmospheric Research and the University of Oklahoma, has targeted the development and improvement of weather prediction models and data assimilation systems to characterize the state of the atmosphere better with the goal of providing superior aviation weather information to enhance NAS safety and capacity. These assimilation and prediction systems use all the latest weather observations and advanced supercomputers to create the most accurate and timely depiction of the future state of the weather. These joint efforts have resulted in a state-of-the-art Grid-point Statistical Interpolation data assimilation system and Weather Research and Forecast modeling framework. A significant result has been the FY 2012 implementation into NWS operations of the hourly updated RAP weather prediction system. This system yields more accurate wind forecasts, as shown below, and improved analyses and forecasts of weather hazardous to aviation, including en-route turbulence, convective weather, in-flight icing, and restricted visibility, over an expanded domain, including Alaska. (Weather Program)

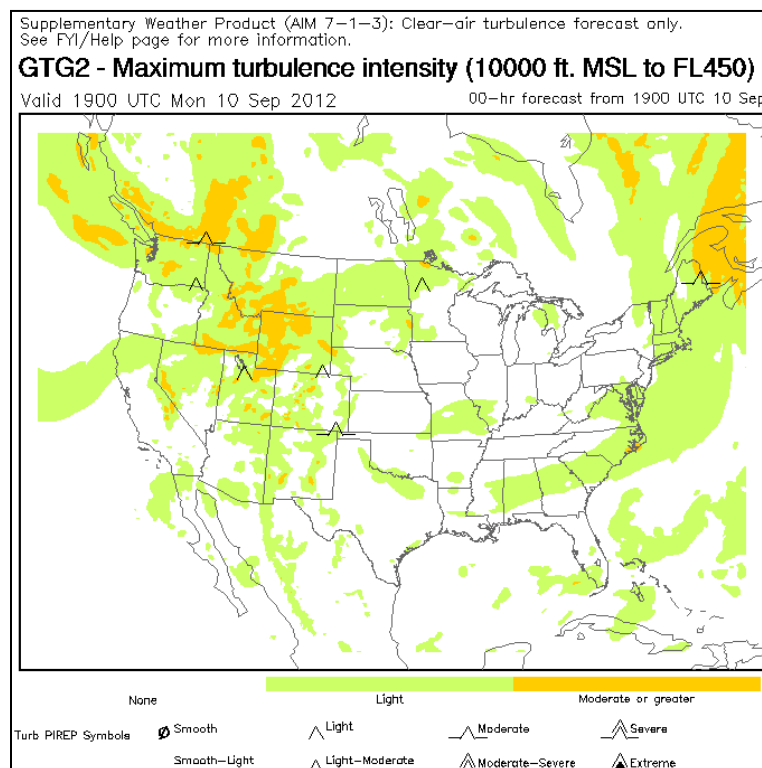


Wind Speed at Altitude Forecast Chart

Forecast Turbulence Algorithm Development:

Commercial and GA aircraft frequently encounter unexpected turbulence. Though rarely fatal, these encounters often result in serious injuries to aircraft occupants and affect NAS efficiency via rerouting of flights. Turbulence is the leading cause of injuries to passengers and flight attendants in non-fatal accidents; and more than 55 passengers in the U.S. suffer injuries in turbulence incidents each year. Because observations and forecasts have not been accurate

enough to pinpoint the location, time, and intensity of turbulence, the FAA has developed a turbulence-forecasting algorithm, called the Graphical Turbulence Guidance (GTG). GTG provides turbulence analyses and forecasts out to 12 hours over the contiguous U.S., parts of Mexico and Canada, the western Atlantic Ocean, and eastern Pacific Ocean at altitudes from 10,000 to 46,000 feet. GTG runs operationally on the Web-based ADDS at the NOAA Aviation Weather Center in Kansas City. In FY 2012, the FAA modified the current GTG algorithm to use outputs from a new numerical weather prediction model, the Weather Research and Forecast RAP, developed and implemented by the NOAA National Center for Environmental Prediction. RAP is a more efficient weather prediction model, than its predecessor, the Rapid Update Cycle, and enhances the accuracy and reliability of the GTG. GTG utilizing RAP outputs went operational on ADDS in FY 2012. The GTG automated algorithms gather real-time information from weather models, in-situ turbulence measurements from aircraft and pilot reports to accurately identify and predict the location and intensity of turbulence in the NAS. (Weather Program)



Graphical Turbulence Guidance (GTG) Forecast Chart

R&D Principle 3 - Reduce Environmental Impacts

Systematically expand and apply knowledge to produce useful materials, devices, systems, or methods that will reduce aviation's environmental and energy impacts to a level that does not constrain growth

Airport Noise and Sleep Annoyance Study:

In FY 2012, the FAA initiated an extensive, multi-year data collection effort to survey communities' level of annoyance in response to aircraft noise. Since the current FAA noise policy is based on human response and noise exposure data from the 1960's and 1970's, this initiative aims to provide the necessary data to allow research experts to update the scientific evidence of the relationship between aircraft noise exposure and annoyance. The results of this study will provide the FAA with the additional confidence that given metrics and levels of noise are indicative of today's population, and also provide the necessary information to serve as a guide for national aviation noise policy and determine community noise impacts and land-use guidelines. (Airport Technology Research Program – Environment)

Aircraft Technology Development under the Continuous Lower Energy, Emissions, and Noise (CLEEN) Program:

In partnership with industry, the Continuous Lower Energy, Emissions, and Noise (CLEEN) Program completed four demonstrations in FY 2012, significantly accelerating technology development and advancing toward commercialization by the end of this decade.

In January 2012, GE completed core engine tests of the TAPS II (twin-annular pre-swirl) Combustor. Results show landing and take-off nitrogen oxide emissions were reduced 60 percent compared to Committee for Aviation Environmental Protection 6 standards, meeting one of the CLEEN goals. CFM International will use this combustor in their LEAP-X turbofan engine, with commercialization expected in 2016. Also in January 2012, GE completed wind tunnel tests of subscale blades for its open rotor engine. Results indicate aircraft fuel burn on a single aisle aircraft may be reduced 26 percent with up to 15 dB margin to current Stage 4 noise standards.

Under another CLEEN-funded technology, Boeing integrated an adaptive trailing edge on a modified 737-800 aircraft, completing ground tests in August 2012, and flight tests in September 2012. The FAA expects this technology to reduce aircraft fuel burn up to two percent by increasing wing aerodynamic efficiency. The technology should also decrease aircraft noise during approach. (Environment and Energy – Environmental Management Systems and Advanced Noise and Emissions Reduction)



Boeing Eco-Demonstrator Aircraft with Adaptive Trailing Edge Technology

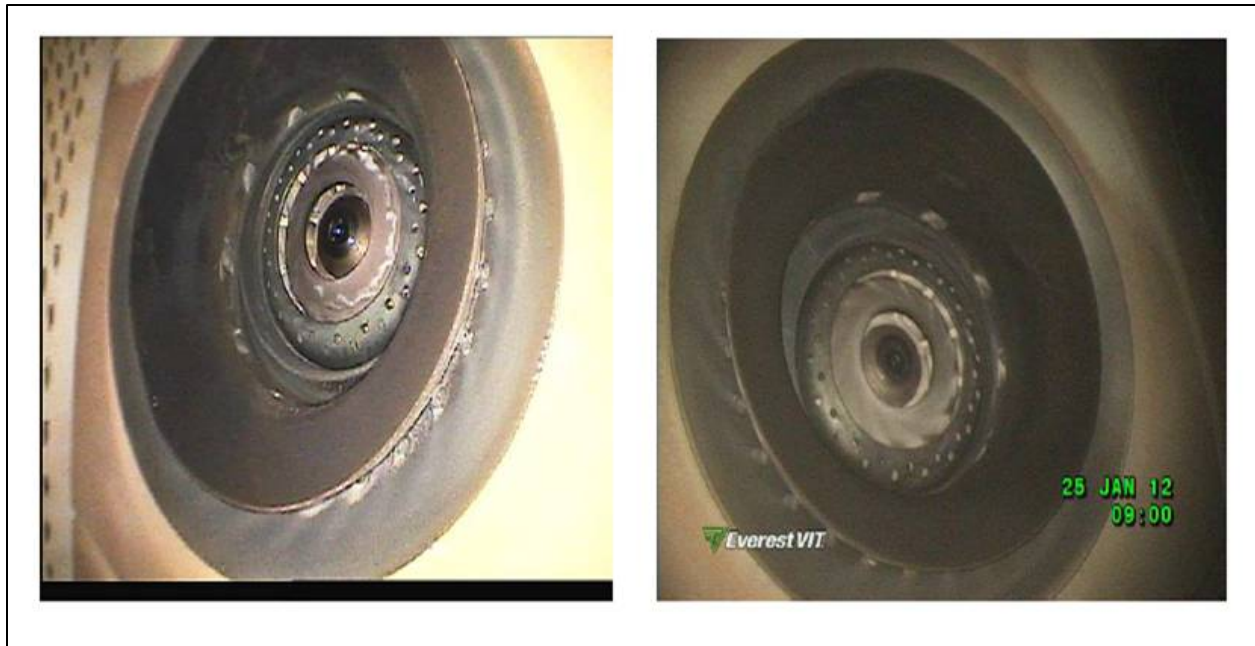
Sustainable Alternative Jet Fuel Development:

Commercial aviation faces a number of challenges, including - fuel cost, environmental impacts, and energy security. Sustainable alternative jet fuels can help address these challenges.

In November 2011, the Feedstock Readiness Level Tool (FSRL), developed jointly by the U.S. Department of Agriculture, the FAA, and the John A. Volpe Transportation Systems Center, was presented to industry and government stakeholders of the Commercial Aviation Alternative Fuels Initiative. The FSRL is a gated risk management tool that can be employed to measure and track progress in the feasibility and availability of the raw materials (or feedstocks) needed to produce sustainable alternative jet fuel. The tool combines aviation's system level gated project development experience with the expertise and needs of agricultural producers.

In February 2012, Honeywell Aerospace completed endurance testing of an HTF7000 turbofan engine using a 50 percent blend of Jet-A and hydroprocessed esters and fatty acids (HEFA) fuel. More than 850 service life cycles were completed, confirming that this already approved jet biofuel blend does not affect long-term engine wear or operation.

In September 2012, UOP Honeywell delivered 100 gallons of an advanced jet biofuel made from a renewable alcohol (isobutanol) raw material. This fuel will be used for rig and engine testing necessary to support alcohol to jet fuel to be approved for commercial use in the next two years. (Environment and Energy – Environmental Management Systems and Advanced Noise and Emissions Reduction)



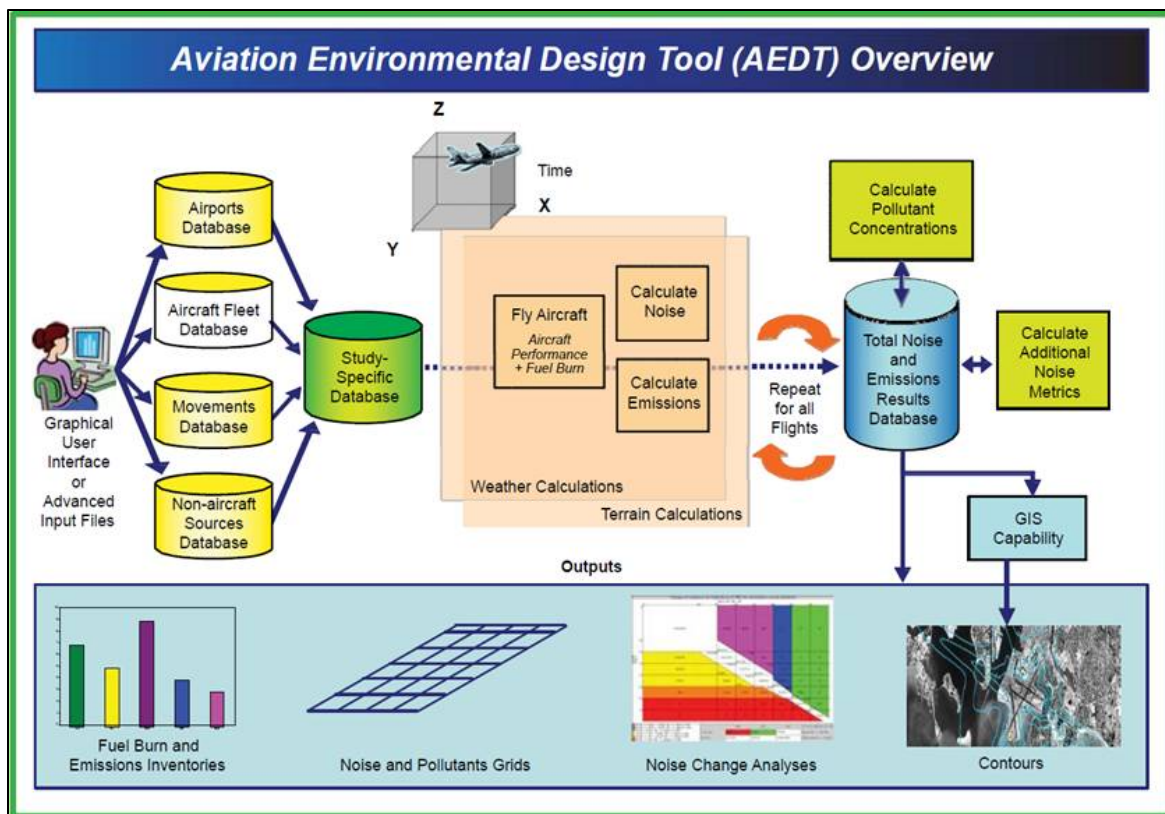
Before and After Images of Engine Durability Testing using HEFA Fuel

Aviation Environmental Design Tool:

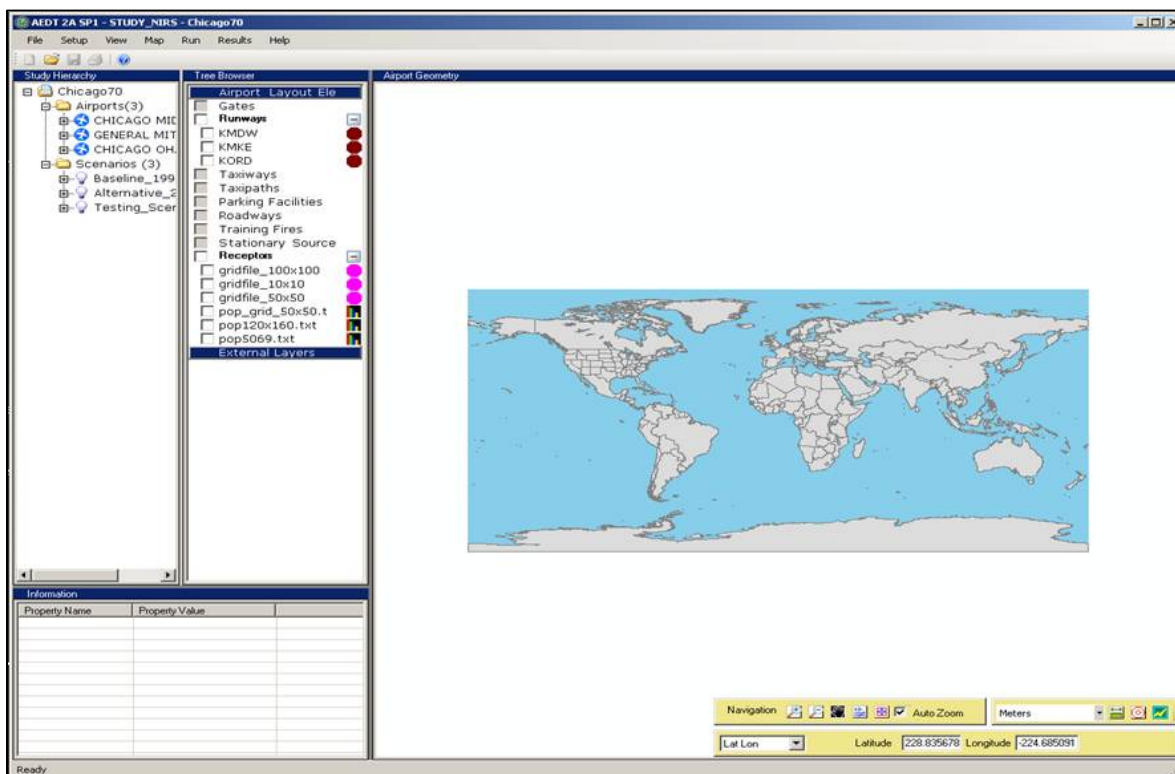
The Aviation Environmental Design Tool (AEDT) version 2a was released to the public on March 21, 2012. AEDT 2a replaces the Noise Integrated Routing System legacy tool for National Environmental Policy Act (NEPA) airspace environmental compliance of air traffic airspace and procedure actions as dictated in Federal Register notice 77 FR 18297. The tool is available

at: http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/aedt/.

In June 2012, AEDT 2a was updated to Service Pack 1 (SP1) to address issues identified with weather and flight performance processing. The next version of AEDT, version 2b, will replace the Integrated Noise Model and Emissions and Dispersion Modeling System (EDMS) legacy tools for NEPA airport environmental compliance analysis. This version will be available to the public in 2014. Several FAA stakeholders are engaged in testing development versions of the tool and providing feedback to the team. Typically, these updated versions are available every two or three weeks. Stakeholders also receive stable interim beta versions. AEDT 2b beta 1 became available on June 30, 2012, beta 2 on October 1, and beta 3 scheduled for release on February 1, 2013. (Safety, Security, Environment – Operational Assessments)



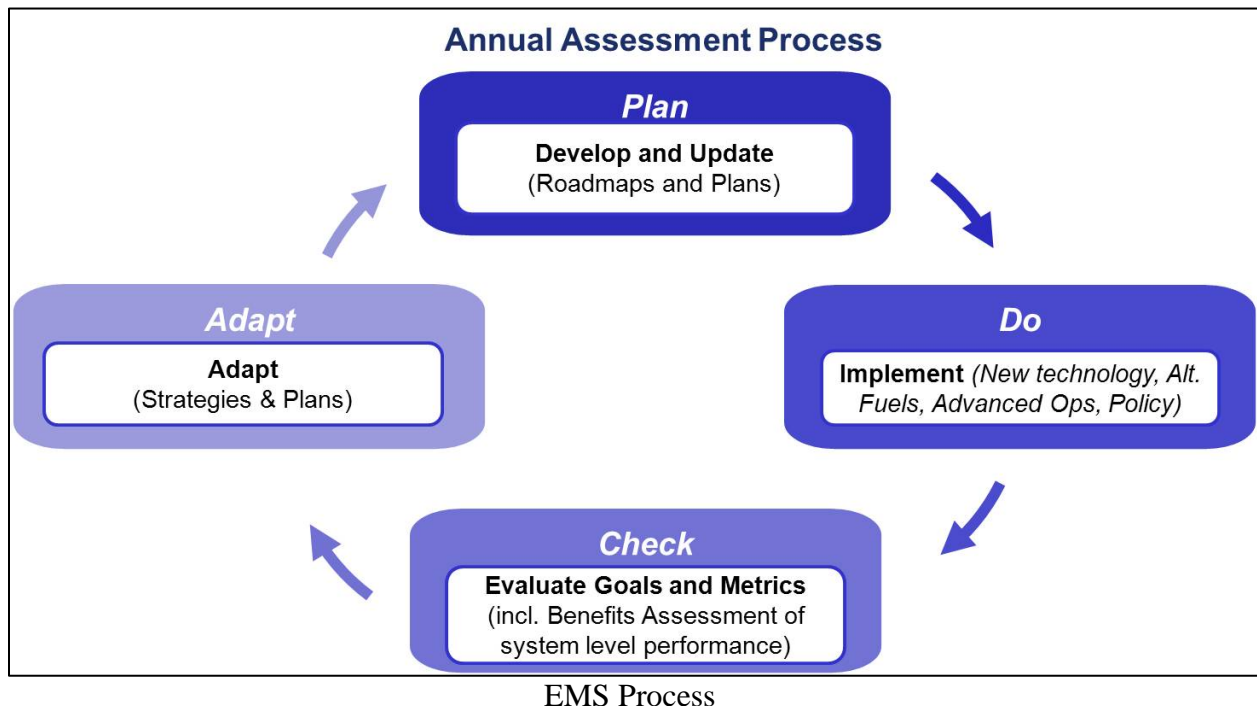
AEDT Overview



AEDT Screenshot

NextGen Environmental Management System Framework:

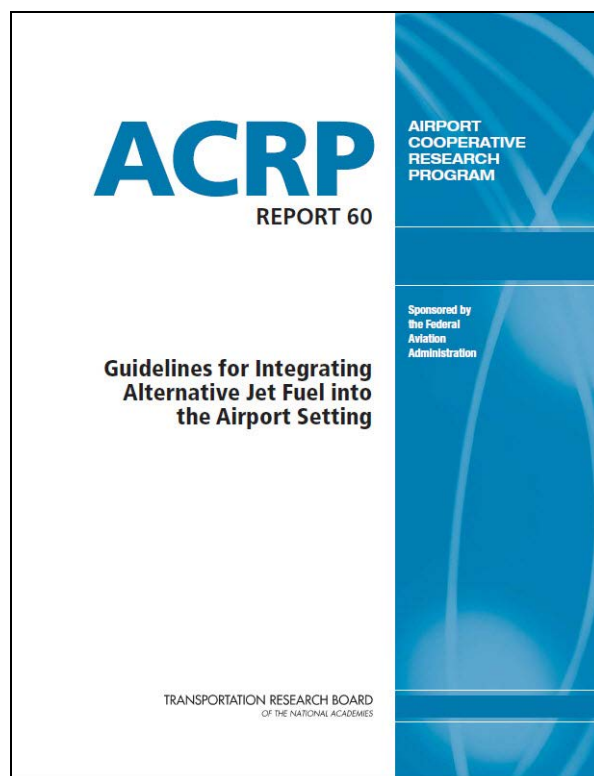
Sustaining future aviation growth, improving efficiency, and increasing flexibility requires aviation stakeholders to collaborate to address potential environmental and energy constraints in their planning and operations. Therefore, the FAA is developing an Environmental Management System (EMS) to foster collaboration across aviation stakeholders and establish an organizational framework to manage long-term environmental and energy issues. The EMS approach aims to maximize environmental and energy benefits while supporting the system level goals articulated through the Aviation Environmental and Energy Policy Statement and FAA strategic planning. This year, the FAA performed work on three core components of the NextGen EMS framework development: (1) Higher Tier/System Level elements; (2) Information Exchange and Collaboration, and (3) Stakeholder Collaboration Program. In particular, the FAA completed Phase II pilot studies to investigate current NextGen implementation efforts to identify best practice approaches to address NEPA requirements. In addition, the FAA began development of a Web-based portal to communicate with stakeholders on aviation environmental and energy issues and began outreach efforts to establish a stakeholder collaboration program. The FAA expects to release this Web portal by the end of 2013. (Environment and Energy – Environmental Management Systems and Advanced Noise and Emissions Reduction)



Guidelines for Integrating Alternative Jet Fuel into the Airport Setting:

Virtually all of the fuel currently used in aviation operations is derived from petroleum. Petroleum fuel supply and associated pricing (both level and volatility) are key business challenges for the aviation industry. In addition, concerns about environmental impacts compound challenges facing the aviation sector as it continues to meet demand. “Drop-in” alternative jet fuel provides great promise for the aviation industry from an environmental, energy security, and economic perspective. Several demonstration flights during the past year have shown that technology is available to produce alternative jet fuel that industry can use to fly existing aircraft safely. Key challenges to moving forward with commercial use of alternative jet fuel include the formation of an effective business plan addressing fuel production at marketable prices and quantities, and deliverable at the appropriate point in the supply chain. One concept that has received significant industry interest is to locate an alternative fuel production facility on, adjacent to, or with access to an airport to take advantage of known demand. Access to a known demand at an airport could encourage investment by an alternative fuel producer in aviation fuel. In order to provide a path forward for siting an alternative fuel production facility and its associated infrastructure, research is necessary to evaluate the legal, financial, environmental, and logistical considerations and opportunities associated with launching such a project.

As a result of this research, the ACRP was able to prepare the handbook *Guidelines for Integrating Alternative Jet Fuel into the Airport Setting* for airport operators and others associated with “drop-in” jet fuel production and delivery that summarizes issues and opportunities associated with locating—either onsite or off—an alternative jet fuel production facility, and its storage and distribution requirements. The handbook identifies potential benefits; addresses legal, financial, environmental, and logistical considerations and opportunities; and aids in evaluating the feasibility of providing this capability. (Airport Cooperative Research Program – Environment)



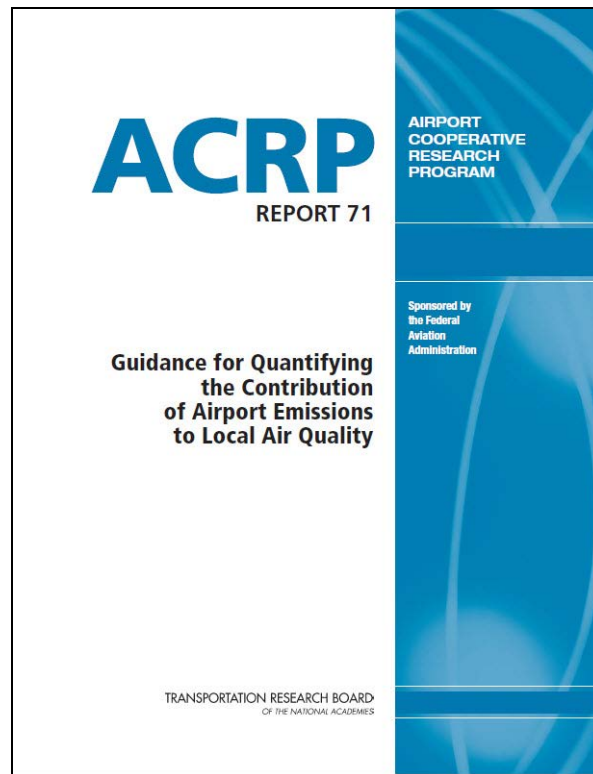
Guidance for Quantifying the Contribution of Airport Emissions to Local Air Quality:

Frequently, airport operators must estimate the magnitude of emissions from airport-related sources, including criteria pollutants and hazardous air pollutants, and quantify the contribution of those emissions to local air quality. Significant advances have been made with respect to estimating emissions from airport-related sources, advances that have been incorporated in the U.S. airport emissions modeling tool - EDMS. However, research has been limited on the relative contribution of airports to local and regional air quality in comparison to non-airport emission sources.

Similar to other sources, emissions of air pollutants released from airport activities are chemically reactive. During their atmospheric evolution, these air pollutants undergo complex transport and physical-chemical processes leading to formation of secondary air pollutants. Besides proper representation of these processes, correct estimation of all airport emissions and their representation in air quality analyses are an essential component in examining the role that airport emissions play in ambient air quality. A combination of ambient air quality measurements and use of modeling tools appears to provide the best framework to extract the needed information. Researchers develop air quality models to predict regional, local, and subscale concentration distributions of air pollutants; however, ambient measurements are necessary to evaluate the predictive capability of these models. Once established to be credible, researchers can reliably use these models to study issues of specific interest.

A combined modeling-measurement approach is often used in air quality analysis; however, its use in airport-related air quality analysis is in its infancy. At present, there are two independent projects planned that will employ this approach for air quality analysis: TF Green International Airport in Providence, Rhode Island, and Los Angeles International Airport. In addition, there are ongoing modeling studies at Chicago O'Hare and ATL airports. Findings from these studies will be valuable for the airports under study; however, to broaden the applicability of these results, there is a need to carry out similar studies for other airports. These additional studies will enable the formulation of detailed guidance for modeling and measurement analysis to estimate airport contributions to ambient air quality. Research is necessary to develop this guidance, assessing and evaluating the state of the art in modeling technology available to airports throughout the country designed to quantify the impact of airport emissions on ambient air quality.

As a result of this project, ACRP published the handbook *Guidance for Quantifying the Contribution of Airport Emissions to Local air Quality* for airport operators on effective tools and techniques for measuring airport contributions to ambient air quality. The research evaluated existing and potential monitoring strategies and forecasting techniques that airport operators can use to measure airport-related air quality impacts on local jurisdictions that may exceed what is traditionally measured and modeled for NEPA purposes. The evaluation process required a selection of a specific airport as a test case for application of a combination of air quality measurement and state-of-the-art modeling techniques and an evaluation of the results of that application. This research identifies gaps in existing models and the inputs to those models, future research needed to fill those gaps to improve the predictive capabilities of available models, a set of detailed recommendations for implementing an optimal emissions monitoring and forecasting strategy, and guidance to airport operators on how to select and carry out that strategy. (Airport Cooperative Research Program – Environment)



Acronym List

Acronym	Definition
0-9	
2D	Two-Dimensional
3D PAM	Three-Dimensional Path Arrival Management
4D	Four-Dimensional
A	
AC	Advisory Circular
ACER	Airliner Cabin Environment Research
ACRP	Airport Cooperative Research Program
ADDS	Aviation Digital Data Service
ADS-B	Automatic Dependent Surveillance–Broadcast
AEDT	Aviation Environmental Design Tool
AHD	Acoustic Hailing Device
Al-Li	Aluminum-Lithium
APM	Automated People Mover
ARFF	Aircraft Rescue and Fire Fighting
ARTCC	Air Route Traffic Control Center
ASIAS	Aviation Safety Information Analysis and Sharing
ATC	Air Traffic Control
ATL	Hartsfield-Jackson Atlanta International Airport
C	
CAASD	Center for Advanced Aviation System Development
CAMI	Civil Aerospace Medical Institute
CDTI	Cockpit Display of Traffic Information
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CIP	Current Icing Product
CLEEN	Continuous Lower Energy, Emissions, and Noise
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
COTS	Commercial-Off-the-Shelf
CRDA	Cooperative Research and Development Agreement
CSET	Composite Structural Engineering Training
CVA	Ceiling and Visibility Analysis
D	
Data Comm	Data Communications
DIC	Digital Image Correlation

Acronym	Definition
DPG	Design Process Guide
E	
EDA	Efficient Descent Advisor
EDMS	Emissions and Dispersion Modeling System
EFB	Electronic Flight Bag
ELSO	Equivalent Lateral Spacing Operation
EMS	Environmental Management System
F	
FAA	Federal Aviation Administration
FASTER	Full-Scale Aircraft Structural Test Evaluation and Research
FDS	Fire Dynamics Simulator
FIP	Forecast Icing Product
FRAT	Flight Risk Analysis Tool
FSRL	Feedstock Readiness Level
FTIR	Fourier Transform Infrared Spectroscopy
G	
GA	General Aviation
GE	General Electric
GTG	Graphical Turbulence Guidance
GWU	The George Washington University
H	
HDDAM	High Density Area Departure/Arrival Management
HEFA	Hydroprocessed Esters and Fatty Acids
HITL	Human In The Loop
I	
IFR	Instrument Flight Rules
ITS	Intelligent Transportation Systems
J	
JPDO	Joint Program Development Office
L	
Li-ion	Lithium-ion
LSTC	Livermore Software Technology Corporation
M	
M&R	Maintenance and Repair
MAP	Mutual Aid Program
MCC	Microscale Combustion Calorimeter
MMPDS	Metallic Materials Properties Development and Standardization

Acronym	Definition
N	
NARP	National Aviation Research Plan
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NDI	Nondestructive Inspections
NDIR	Non-Dispersive Infrared
NEPA	National Environmental Policy Act
NextGen	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NTSB	National Transportation Safety Board
O	
OSU	Ohio State University
P	
PBN	Performance-based Navigation
PDTA	Probabilistic Damage Tolerance Analysis
PED	Portable Electronic Device
PMMA	Polymethyl methacrylate
POD	Probability of Detection
R	
R&D	Research and Development
RAP	Rapid Refresh
RF	Radius-to-fix
RITE	National Air Transportation Center of Excellence for Research in the Intermodal Transport Environment
RNAV	Area Navigation
RNP	Required Navigation Performance
RTA	Required Time of Arrival
S	
SAE	Society of Automotive Engineers
SCLA	Southern California Logistics Airport
SEADOG	Southeastern Airports Disaster Operations Group
SHM	Structural Health Monitoring
SL	Service Load
SMS	Safety Management System
SP1	Service Pack 1
T	
TAPS	Twin-Annular Pre-Swirl
TCP	Tricresyl Phosphate

Acronym	Definition
TRACON	Terminal Radar Approach Control
U	
U.S.	United States
UT	Ultrasonic Testing
W	
WestDOG	Western Airports Disaster Operations Group
WJHTC	William J. Hughes Technical Center